Preamble and Contents Effective: 01/01/2014

The following is a list of AMC-20 affected by this amendment.

AMC 20-115	amended (NPA 2012-11)
AMC 20-2	amended (NPA 2012-11)
AMC 20-3	amended (NPA 2012-11)
AMC 20-4	amended (NPA 2012-11)
AMC 20-27	amended (NPA 2012-11)

The following revised AMC-20 are replacing AMC 20-115B, AMC 20-1 2nd Issue, AMC 20-2, AMC 20-3, AMC 20-4 and AMC 20-27:

General Acceptable Means of Compliance for Airworthiness of Products, Parts and Appliances

AMC-20

…

AMC 20-115C

…

AMC 20-2A

AMC 20-3A

AMC 20-4A

…

AMC 20-27A

…

AMC 20-115C
Software Considerations for Certification of Airborne Systems and Equipment

1 PURPOSE

This Acceptable Means of Compliance (AMC) provides a means that can be used to demonstrate that the safety aspects of software hosted on airborne systems and equipment comply with requirements for initial airworthiness in order to obtain an airworthiness approval.

Compliance with this AMC is not mandatory and hence an applicant may elect to use an alternative means of compliance. However, those alternative means of compliance must meet the relevant requirements, ensure an equivalent level of software safety and be approved by the European Aviation Safety Agency on a product basis.

In particular, the purpose of this AMC is to provide guidelines for the production of software for airborne systems and equipment that performs its intended function with a level of confidence in safety that complies with airworthiness requirements.

2 SCOPE

This AMC discusses those aspects of airworthiness certification that pertain to the production of software for airborne systems and equipment used on aircraft, engines, propellers, APU or others parts.

In discussing those aspects, the system life cycle and its relationship with the software life cycle are considered to aid in the understanding of the certification process.

Other system and software life cycle processes are out of scope of the present AMC. For instance, out of scope are:

- system safety assessment and validation processes at product level, in the context of initial airworthiness certification of aircraft and engines;
- software considerations for the verification of ground and space systems and constituents of Air Traffic Management (ATM)/Air Navigation Services (ANS);
- software considerations for services consisting of the origination and processing of data and formatting and delivering data to general air traffic for the purpose of safety-critical air navigation;

Since certification issues for initial airworthiness are discussed only in relation to the software life cycle, the operational aspects of the resulting software are not discussed. For example, the certification, approval and management aspects of user-modifiable data are beyond the scope of this AMC.

This AMC does not provide guidelines concerning the structure of the applicant's organisation, the relationships between the applicant and its suppliers, or how the responsibilities are divided.

Personnel qualification criteria are also beyond the scope of this AMC.

3 PROCEDURES, METHODS AND TOOLS FOR SOFTWARE CONSIDERATIONS

This AMC recognises that the European Organisation for Civil Aviation Equipment (EUROCAE) document ED-12C, 'Software Considerations in Airborne Systems and Equipment Certification', issued in January 2012, related guidance documents and supplements or equivalent RTCA Inc. documents, constitute an acceptable means of compliance for software (SW).

Aspects of certification that pertain to the production of software for airborne systems and equipment used on aircraft, engines, propellers and, by region, auxiliary power units. It discusses how the document may be applied to certification programmes administered by the European Aviation Safety Agency.

4 RELATED DOCUMENTS

4.1 EUROCAE document ED-12C, 'Software Considerations in Airborne Systems and Equipment Certification', describes the acceptable processes to develop and verify SW for airborne systems and equipment.

4.2 EUROCAE document ED-12C is technically equivalent to RTCA Inc. document DO-178C. A reference to one document, at the same revision level, may be interpreted to mean either document.

4.3 ED-12C/DO-178C guidance is extended with the following related documents and supplements:

- ED-94C/DO-248C 'Supporting Information for ED-12C and ED-109A' ;
- ED-215/DO-330 'Software Tool Qualification Considerations';
- ED-216/DO-333 'Formal Methods Supplement to ED-12C and ED-109A';
- ED-217/DO-332 'Object-Oriented Technology and Related Techniques Supplement to ED-12C and ED-109A'; and
- ED-218/DO-331 'Model-based Development and Verification Supplement to ED-12C and ED-109A'.

4.4 The technical content of this AMC is as far as practicable harmonised with the latest edition of FAA AC 20-115[1], equally based on ED-12/DO-178.

5 RELATED CERTIFICATION SPECIFICATIONS (CSs)

Part 21, CS-22, CS-23, CS-25, CS-27, CS-29, CS-AWO, CS-E, CS-P, CS-APU, CS-ETSO and CS-VLA. Existing references to ED-12/DO-178, ED-12A/DO-178A and ED-12B/DO-178B in the above CSs will be replaced by reference to this AMC to provide a single source of regulatory material on airborne software development for airborne systems and, equipment used on aircraft, engines, propellers and auxiliary power units.

6 BACKGROUND

EUROCAE document ED-12C was developed to establish software considerations for aircraft system or equipment developers when the aircraft system and equipment design is developed using software based techniques. Current and future avionics designs make extensive use of this technology. The EUROCAE document provides guidance for establishing software life cycle planning, development, verification, configuration management, quality assurance and certification liaison processes to be used in software based systems.

[1] AC 20-115C of 19 July 2013: http://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.information/documentID/1021710

The guidance provided in ED-12C is in the form of:

- objectives for software life-cycle processes;
- descriptions of activities and design considerations for achieving those objectives; and
- descriptions of the evidence that indicates that the objectives have been satisfied.

ED-94C document was developed to provide supporting information and clarification of ED-12C.
ED-215 is a document that was developed to provide tool qualification guidance. ED-215 is invoked in ED-12C (section 12.2.3 Tool Qualification Process) and provides the objectives, activities, guidance, and life cycle data required for each Tool Qualification Level.
ED-216 is a supplement to ED-12C that was developed to provide specific guidance regarding Formal Methods.
ED-217 is a supplement to ED-12C that was developed to provide specific guidance regarding Object-Oriented Technology and Related Techniques.
ED-218 is a supplement to ED-12C that was developed to provide specific guidance regarding the techniques of Model-based Development and Verification.
Whenever one or more of the techniques addressed by these last three supplements is used in software based systems, the corresponding supplement or supplements to ED-12C should be applied in addition to ED-12C itself.

ED-12C and its related supplements specify the information to be made available and/or delivered to the Agency. Guidance is also provided for dealing with software developed to earlier standards, tool qualification and alternative methods that may be used.

7 USE OF EUROCAE ED-12C AND RELATED DOCUMENTS AND SUPPLEMENTS

An applicant to EASA for product certification or ETSO authorisation for any software–based equipment or system may use the considerations outlined in EUROCAE document ED-12C and its related documents and applicable supplements, as a means, but not the only means, to secure approval. The Agency may publish acceptable means of compliance for specific CSs, stating the required relationship between the criticality of the software based systems and the software levels as defined in EUROCAE document ED-12C. Such acceptable means of compliance will take precedence over the application of EUROCAE document ED-12C.

8 USE OF PREVIOUS VERSIONS

8.1 Previous ED-12 versions may continue to be accepted for modifications to the software of already approved systems and equipment or for reuse of already approved software components in new application for certification of products or part and appliances.

8.2 Paragraph 8.1 applies, provided that:

- The software level is not higher;
- The techniques described in the ED-12C supplements (MBD, OOTRT, Formal Methods) are not introduced into the new project; otherwise, ED-216 and/or ED-217 and/or ED-218 should be applied;
- the change to the ETSO authorized article is minor (see 21A.611);
- No new software criteria 1 or 2 tool qualification is needed; otherwise ED-215 should be applied only on the new software criteria 1 or 2 tools if the existing tools are not significantly changed;

- No new Parameter Data Item files are introduced, otherwise ED-12C should only be applied on the new Parameter Data Item files if the existing PDIs are not significantly changed and it should be demonstrated that software using the new Parameter Data Item files is compliant with the ED-12C sections related to Parameter Data Item;
- Software plans, processes, and life cycle environment, including process improvements have been maintained;

8.3 Where a modification is made to an existing software-based equipment or system, and the criteria in this section indicate the use of ED-12C and related supplements, they may apply, under justification, only to the software components affected by the modification.

For major changes to ETSO authorised articles, a previous version of ED-12 may continue to be accepted under justification.

Early coordination with EASA is strongly recommended to validate the above assumptions.

9 AVAILABILITY OF EUROCAE DOCUMENTS

Copies may be purchased from EUROCAE, 102 rue Étienne Dolet, 92240 Malakoff, France, (Fax : 33 1 46 55 62 65).

AMC 20-2A
Certification of Essential APU Equipped with Electronic Controls

1. GENERAL

The existing regulations for APU and aircraft certification may require special interpretation for essential APU equipped with electronic control systems. Because of the nature of this technology it has been found necessary to prepare acceptable means of compliance specifically addressing the certification of these control systems.

Like any acceptable means of compliance, the content of this document is not mandatory. It is issued for guidance purposes, and to outline a method of compliance with the airworthiness code. In lieu of following this method, an alternative method may be followed, provided that this is agreed by the Agency as an acceptable method of compliance with the airworthiness code.

This document discusses the compliance tasks relating to both the APU and the aircraft certification.

2 REFERENCE SPECIFICATIONS

2.1 *APU Certification*

CS-APU

Book 1, paragraph 2(c)

Book 1, Section A, paragraphs 10(b), 20, 80, 90, 210, 220, 280 and 530

Book 2, Section A, AMC CS-APU 20

2.2 *Aircraft Certification*

Aeroplane: CS-25

Paragraphs 581, 899, 1301, 1307(c), 1309, 1351(b)(d), 1353(a)(b), 1355(c), 1357, 1431, 1461, 1524, 1527

A9011, A903, A939, A1141, A1181, A1183, A1189, A1305, A1337, A1521, A1527, B903, B1163

3 SCOPE

This acceptable means of compliance provides guidance for electronic (analogue and digital) essential APU control systems, on the interpretation and means of compliance with the relevant APU and aircraft certification requirements.

It gives guidance on the precautions to be taken for the use of electronic technology for APU control, protection and monitoring and, where applicable, for integration of functions specific to the aircraft.

Precautions have to be adapted to the criticality of the functions. These precautions may be affected by -

Degree of authority of the system,

Phase of flight,

Availability of back-up system.

This document also discusses the division of compliance tasks between the APU and aircraft certification.

4 PRECAUTIONS

4.1 *General*

The introduction of electronic technology can entail the following:

(a) A greater dependence of the APU on the aircraft owing to the use of electrical power and/or data supplied from the aircraft,

(b) Risk of significant failures which might, for example, occur as a result of -

(i) Insufficient protection from electromagnetic disturbance (lightning, internal or external radiation effects),

(ii) Insufficient integrity of the aircraft electrical power supply,

(iii) Insufficient integrity of data supplied from the aircraft,

(iv) Hidden design faults or discrepancies contained within the design of the APU control software, or

(v) Omissions or errors in the system specification.

Special design and integration precautions must therefore be taken to minimise these risks.

4.2 *Objective*

The introduction of electronic control systems should provide for the aircraft at least the equivalent safety, and the related reliability level, as achieved by essential APU equipped with hydro-mechanical control and protection systems.

This objective, when defined during the aircraft/APU certification for a specific application, will be agreed with the Agency.

4.3 *Precautions relating to APU control, protection and monitoring*

The software associated with APU control, protection and monitoring functions must have a software level and architecture appropriate to their criticality (see paragraph 4.2).

For digital systems, any residual errors not activated during the software development and certification process could cause an unacceptable failure. The latest edition of AMC 20-115 constitutes an acceptable means of compliance for software development, verification and software aspects of certification. The APU software should be at least level B according to the industry documents referred in the latest edition of AMC 20-115. In some specific cases, level A may be more appropriate.

It should be noted the software disciplines described in the latest edition of AMC 20-115 may not, in themselves, be sufficient to ensure that the overall system safety and reliability targets have been achieved. This is particularly true for certain critical systems, such as fully authority digital control systems. In such cases it is accepted that other measures, usually within the system, in addition to a high level of software discipline may be necessary to achieve these safety objectives and demonstrate that they have been met.

It is outside the scope of the latest edition of AMC 20-115 to suggest or specify these measures, but in accepting that they may be necessary, it is also the intention to encourage the development of software techniques which could support meeting the overall system safety objectives.

4.4 *Precautions relating to APU independence from the aircraft*

4.4.1 *Precautions relating to electrical power supply and data from the aircraft*

When considering the objectives of paragraph 4.2, due consideration must be given to the reliability of electrical power and data supplied to the electronic controls and peripheral components. Therefore the potential adverse effects on APU operation of any loss of electrical power supply from the aircraft or failure of data coming from the aircraft must be assessed during the APU certification.

(a) Electrical power

The use of either the aircraft electrical power network or electrical power sources specific to the APU, or the combination of both, may meet the objectives.

If the aircraft electrical system supplies power to the APU control system at any time, the power supply quality, including transients or failures, must not lead to a situation identified during the APU certification which is considered during the aircraft certification to be a hazard to the aircraft.

(b) Data

The following cases should be considered:

(i) Erroneous data received from the aircraft by the APU control system, and

(ii) Control system operating faults propagating via data links.

In certain cases, defects of aircraft input data may be overcome by other data references specific to the APU in order to meet the objectives.

4.4.2 *Local Events*

(a) In designing an electronic control system to meet the objectives of paragraph 4.2, special consideration needs to be given to local events.

Examples of local events include fluid leaks, mechanical disruptions, electrical problems, fires or overheat conditions. An overheat condition results when the temperature of the electronic control unit is greater than the maximum safe design operating temperature declared during the APU certification. This situation can increase the failure rate of the electronic control system.

(b) Whatever the local event, the behaviour of the electronic control system must not cause a hazard to the aircraft. This will require consideration of effects such as the overspeed of the APU.

When the demonstration that there is no hazard to the aircraft is based on the assumption that there exists another function to afford the necessary protection, it must be shown that this function is not rendered inoperative by the same local event (including destruction of wires, ducts, power supplies).

(c) Specific design features or analysis methods may be used to show compliance with respect to hazardous effects. Where this is not possible, for example due to the variability or the complexity of the failure sequence, then testing may be required. These tests must be agreed with the Agency.

4.4.3 *Lightning and other electromagnetic effects*

Electronic control systems are sensitive to lightning and other electromagnetic interference. The system design must incorporate sufficient protection in order to ensure the functional integrity of the control system when subjected to designated levels of electric or electromagnetic inductions, including external radiation effects.

The validated protection levels for the APU electronic control system must be detailed during the APU certification in an approved document. For aircraft certification, it must be substantiated that these levels are adequate.

4.5 *Other functions integrated into the electronic control system*

If functions other than those directly associated with the control of the APU are integrated into the electronic control system, the APU certification should take into account the applicable aircraft requirements.

5 INTER-RELATION BETWEEN APU AND AIRCRAFT CERTIFICATION

5.1 *Objective*

To satisfy the CS aircraft requirements, such as CS 25A901, CS 25A903 and CS 25.1309, an analysis of the consequences of failures of the system on the aircraft has to be made. It should be ensured that the software levels and safety and reliability objectives for the electronic control system are consistent with these requirements.

5.2 *Interface definition*

The interface has to be identified for the hardware and software aspects between the APU and aircraft systems in the appropriate documents.

The APU documents should cover in particular -

(a) The software quality level (per function if necessary),

(b) The reliability objectives for -

APU shut-down in flight,

Loss of APU control or significant change in performance,

Transmission of faulty parameters,

(c) The degree of protection against lightning or other electromagnetic effects (e.g. level of induced voltages that can be supported at the interfaces),

(d) APU and aircraft interface data and characteristics, and

(e) Aircraft power supply and characteristics (if relevant).

5.3 *Distribution of compliance demonstrations*

The certification of the APU equipped with electronic controls and of the aircraft may be shared between the APU certification and aircraft certification. The distribution between the APU certification and the aircraft certification must be identified and agreed with the Agency and/or the appropriate APU and aircraft Authorities (an example is given in appendix).

Appropriate evidence provided for APU certification should be used for aircraft certification. For example, the quality of any aircraft function software and aircraft/APU interface logic already demonstrated for APU certification should need no additional substantiation for aircraft certification.

Aircraft certification must deal with the specific precautions taken in respect of the physical and functional interfaces with the APU.

APPENDIX

An example of tasks distribution between APU and aircraft certification

FUNCTIONS OR INSTALLATION CONDITIONS	SUBSTANTIATION UNDER CS-APU	SUBSTANTIATION UNDER CS-25	
APU CONTROL AND PROTECTION	- Safety objective - Software level	- Reliability - Software level	
MONITORING	- Independence of control and monitoring parameters	- Monitoring parameter reliability	- Indication system reliability
AIRCRAFT DATA	- Protection of APU from aircraft data failures - Software level		- Aircraft data reliability
CONTROL SYSTEM ELECTRICAL SUPPLY			- Reliability and quality of aircraft supply if used

AMC 20-3A

Certification of Engines Equipped with Electronic Engine Control Systems

TABLE OF CONTENTS

(1) PURPOSE

The existing certification specifications of CS-E for Engine certification may require specific interpretation for Engines equipped with Electronic Engine Control Systems (EECS), with special regard to interface with the certification of the aircraft and/or Propeller when applicable. Because of the nature of this technology, it has been considered useful to prepare acceptable means of compliance specifically addressing the certification of these control systems.

Like any acceptable means of compliance, it is issued to outline issues to be considered during demonstration of compliance with the Engine certification specifications.

(2) SCOPE

This acceptable means of compliance is relevant to Engine certification specifications for EECS, whether using electrical or electronic (analogue or digital) technology. This is in addition to other acceptable means of compliance such as AMC E 50 or AMC E 80.

It gives guidance on the precautions to be taken for the use of electrical and electronic technology for Engine control, protection, limiting and monitoring functions, and, where applicable, for integration of aircraft or Propeller functions. In these latter cases, this document is applicable to such functions integrated into the EECS, but only to the extent that these functions affect compliance with CS-E specifications.

The text deals mainly with the thrust and power functions of an EECS, since this is the prime function of the Engine. However, there are many other functions, such as bleed valve control, that may be integrated into the system for operability reasons. The principles outlined in this AMC apply to the whole system.

This document also discusses the division of compliance tasks for certification between the applicants for Engine, Propeller (when applicable) and aircraft type certificates. This guidance relates to issues to be considered during engine certification. AMC 20-1 addresses issues associated with the engine installation in the aircraft.

The introduction of electrical and electronic technology can entail the following:

- a greater dependence of the Engine on the aircraft owing to the increased use of electrical power or data supplied from the aircraft,
- an increased integration of control and related indication functions,
- an increased risk of significant Failures common to more than one Engine of the aircraft which might, for example, occur as a result of:
  - Insufficient protection from electromagnetic disturbance (lightning, internal or external radiation effects) (see CS-E 50 (a)(1), CS E-80 and CS-E 170),
  - Insufficient integrity of the aircraft electrical power supply (see CS-E 50 (h)),
  - Insufficient integrity of data supplied from the aircraft (see CS-E 50 (g)),
  - Hidden design Faults or discrepancies contained within the design of the propulsion system control software or complex electronic hardware (see CS-E 50 (f)), or
  - Omissions or errors in the system/software specification (see CS-E 50 (f)).

Special design and integration precautions should therefore be taken to minimise any adverse effects from the above.

(3) RELEVANT SPECIFICATIONS AND REFERENCE DOCUMENTS

Although compliance with many CS-E specifications might be affected by the Engine Control System, the main paragraphs relevant to the certification of the Engine Control System itself are:

CS-E Specification	Turbine Engines	Piston Engines
CS-E 20 (Engine configuration and interfaces)	✓	✓
CS-E 25 (Instructions for Continued Airworthiness),	✓	✓
CS-E 30 (Assumptions),	✓	✓
CS-E 50 (Engine Control System)	✓	✓
CS-E 60 (Provision for instruments)	✓	✓
CS-E 80 (Equipment)	✓	✓
CS-E 110 (Drawing and marking of parts - Assembly of parts)	✓	✓
CS-E 130 (Fire prevention)	✓	✓
CS-E 140 (Tests-Engine configuration)	✓	✓
CS-E 170 (Engine systems and component verification)	✓	✓
CS-E 210 (Failure analysis)		✓
CS-E 250 (Fuel System)		✓
CS-E 390 (Acceleration tests)		✓
CS-E 500 (Functioning)	✓	
CS-E-510 (Safety analysis)	✓	
CS-E 560 (Fuel system)	✓	
CS-E 745 (Engine Acceleration)	✓	
CS-E 1030 (Time limited dispatch)	✓	✓

The following documents are referenced in this AMC 20-3:

- International Electrotechnical Commission (IEC), Central Office, 3, rue de Varembé, P.O. Box 131, CH - 1211 GENEVA 20, Switzerland
  - IEC/PAS 62239, Electronic Component Management Plans, edition 1.0, dated April 2001.
  - IEC/PAS 62240, Use of Semiconductor Devices Outside Manufacturers' Specified Temperature Ranges, edition 1.0, dated April 2001.
- RTCA, Inc. 1828 L Street, NW, Suite 805, Washington, DC 20036 or EUROCAE, 17, rue Hamelin, 75116 Paris, France
  - RTCA DO-254/ EUROCAE ED-80, Design Assurance Guidance for Airborne Electronic Hardware, dated April 19, 2000.
  - RTCA DO-160/EUROCAE ED 14, Environmental Conditions and Test Procedures for Airborne Equipment.
- AMC 20-115 on software considerations for certification of airborne systems and equipment.
- Aeronautical Systems Center, ASC/ENOI, Bldg 560, 2530 Loop Road West, Wright-Patterson AFB, OH, USA, 45433-7101
  - MIL-STD-461E, Requirements for the Control of Electromagnetic Interference Characteristics, dated August 20, 1999

- MIL-STD-810 E or F, Test Method Standard for Environmental Engineering, E dated July 14, 1989, F dated January 1, 2000

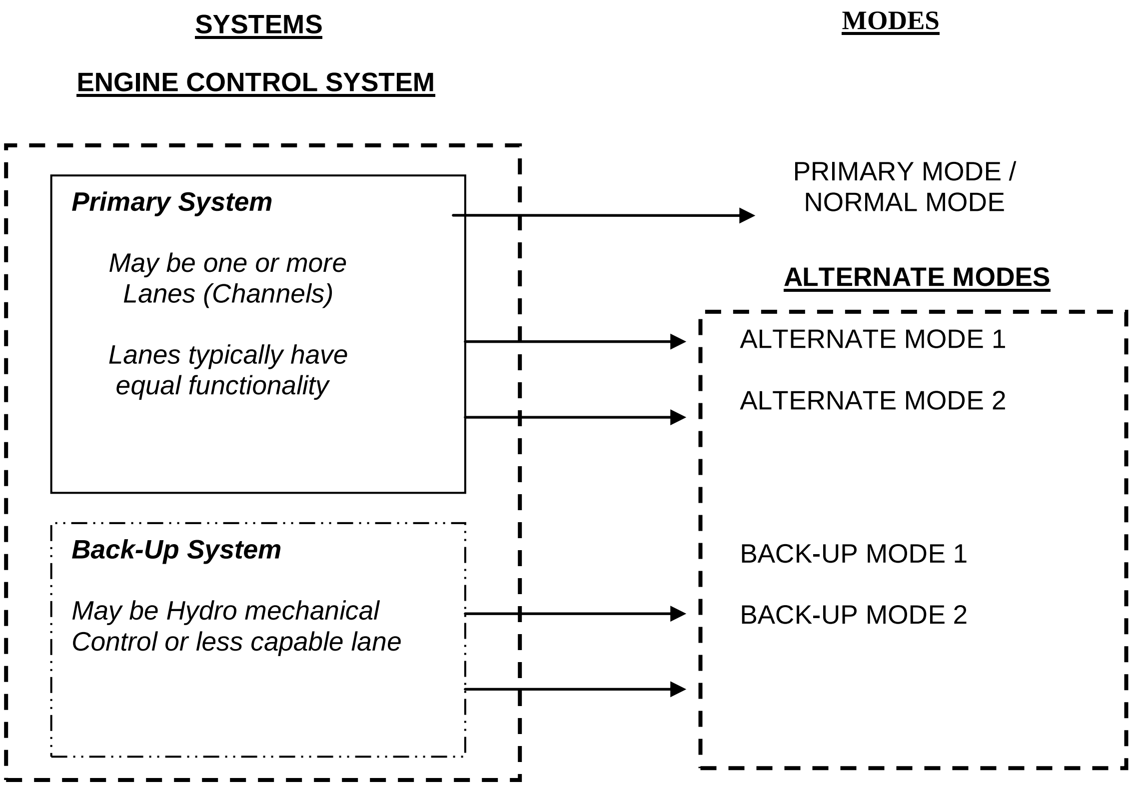
- U.S. Department of Transportation, Subsequent Distribution, Office Ardmore East Business Center, 3341 Q 75th Ave, Landover, MD, USA, 20785
  - AC 20-136, Protection of Aircraft Electrical/Electronic Systems Against the Indirect Effects of Lightning, dated March 5, 1990
- Society of Automotive Engineers (SAE), 400 Commonwealth Drive, Warrendale, PA 15096-0001 USA or EUROCAE, 17, rue Hamelin, 75116 Paris, France
  - SAE ARP 5412 / EUROCAE ED-84, with Amendment 1 & 2, Aircraft Lightning Environment and Related Test Waveforms, February 2005/May 2001 respectively.
  - SAE ARP 5413 / EUROCAE ED-81, with Amendment 1, Certification of Aircraft Electrical/Electronic Systems for the Indirect Effects of Lightning, November 1999/August 1999 respectively.
  - SAE ARP 5414 / EUROCAE ED-91, with Amendment 1, Aircraft Lightning Zoning, February 2005/June 1999 respectively.
  - SAE ARP 5416 / EUROCAE ED-105, Aircraft Lightning Test Methods, March 2005/April 2005 respectively.

(4) DEFINITIONS

The words defined in CS-Definitions and in CS-E 15 are identified by capital letter.

The following figure and associated definitions are provided to facilitate a clear understanding of the terms used in this AMC.

DEFINITIONS VISUALISED



(5) GENERAL

It is recognised that the determination of compliance of the Engine Control System with applicable aircraft certification specifications will only be made during the aircraft certification.

In the case where the installation is unknown at the time of Engine certification, the applicant for Engine certification should make reasonable installation and operational assumptions for the target installation. Any installation limitations or operational issues will be noted in the instructions for installation or operation, and/or the Type Certificate Data Sheet (TCDS) (see CS-E 30).

When possible, early co-ordination between the Engine and the aircraft applicants is recommended in association with the relevant authorities as discussed under paragraph (15) of this AMC.

(6) SYSTEM DESIGN AND VALIDATION

(a) Control Modes - General

Under CS-E 50 (a) the applicant should perform all necessary testing and analysis to ensure that all Control Modes, including those which occur as a result of control Fault Accommodation strategies, are implemented as required.

The need to provide protective functions, such as over-speed protection, for all Control Modes, including any Alternate Modes, should be reviewed under the specifications of CS-E 50 (c), (d) and (e), and CS-E 210 or CS-E 510.

Any limitations on operations in Alternate Modes should be clearly stated in the Engine instructions for installation and operation.

Descriptions of the functioning of the Engine Control System operating in its Primary and any Alternate Modes should be provided in the Engine instructions for installation and operation.

Analyses and/or testing are necessary to substantiate that operating in the Alternate Modes has no unacceptable effect on Engine durability or endurance. Demonstration of the durability and reliability of the control system in all modes is primarily addressed by the component testing of CS-E 170. Performing some portion of the Engine certification testing in the Alternate Mode(s) and during transition between modes can be used as part of the system validation required under CS-E 50 (a).

(i) Engine Test Considerations

If the Engine certification tests defined in CS-E are performed using only the Engine Control System's Primary Mode in the Full-up Configuration and if approval for dispatch in the Alternate Mode is requested by the applicant under CS-E 1030, it should be demonstrated, by analysis and/or test, that the Engine can meet the defined test-success criteria when operating in any Alternate mode that is proposed as a dispatchable configuration as required by CS E-1030.

Some capabilities, such as operability, blade-off, rain, hail, bird ingestion, etc, may be lost in some control modes that are not dispatchable. These modes do not require engine test demonstration as long as the installation and operating instructions reflect this loss of capability.

(ii) Availability

Availability of any Back-up Mode should be established by routine testing or monitoring to ensure that the Back-up Mode will be available when needed. The frequency of establishing its availability should be documented in the instructions for continued airworthiness.

(b) Crew Training Modes

This acceptable means of compliance is not specifically intended to apply to any crew training modes. These modes are usually installation, and possibly operator, specific and need to be negotiated on a case-by-case basis. As an example, one common application of crew training modes is for simulation of the 'failed-fixed' mode on a twin-engine rotorcraft. Training modes should be described in the Engine instructions for installation and operation as appropriate. Also, precautions should be taken in the design of the Engine Control System and its crew interfaces to prevent inadvertent entry into any training modes. Crew training modes, including lock-out systems, should be assessed as part of the System Safety Analysis (SSA) of CS-E 50 (d).

(c) Non-Dispatchable Configurations and Modes

For control configurations which are not dispatchable, but for which the applicant seeks to take credit in the system LOTC/LOPC analysis, it may be acceptable to have specific operating limitations. In addition, compliance with CS-E 50 (a) does not imply strict compliance with the operability specifications of CS-E 390, CS-E 500 and CS-E 745 in these non-dispatchable configurations, if it can be demonstrated that, in the intended installation, no likely pilot control system inputs will result in Engine surge, stall, flame-out or unmanageable delay in power recovery. For example, in a twin-engine rotorcraft, a rudimentary Back-up System may be adequate since frequent and rapid changes in power setting with the Back-up System may not be necessary.

In addition to these operability considerations, other factors which should be considered in assessing the acceptability of such reduced-capability Back-up Modes include:

- The installed operating characteristics of the Back-up Mode and the differences from the Primary Mode.
- The likely impact of the Back-up Mode operations on pilot workload, if the aircraft installation is known.
- The frequency of transfer from the Primary Mode to the Back-up Mode (i.e. the reliability of the Primary Mode). Frequencies of transfer of less than 1 per 20 000 engine flight hours have been considered acceptable.

(d) Control Transitions

The intent of CS-E 50 (b) is to ensure that any control transitions, which occur as a result of Fault Accommodation, occur in an acceptable manner.

In general, transition to Alternate Modes should be accomplished automatically by the Engine Control System. However, systems wherein pilot action is required to engage the Back-up Mode may also be acceptable. For instance, a Fault in the Primary System may result in a 'failed-fixed' fuel flow and some action is required by the pilot to engage the Back-up System in order to modulate Engine power. Care should be taken to ensure that any reliance on manual transition is not expected to pose an unacceptable operating characteristic, unacceptable crew workload or require exceptional skill.

The transient change in power or thrust associated with transfer to Alternate Modes should be reviewed for compliance with CS-E 50 (b). If available, input from the installer should be considered. Although this is not to be considered a complete list, some of the items that should be considered when reviewing the acceptability of Control Mode transitions are:

- The frequency of occurrence of transfers to any Alternate Mode and the capability of the Alternate Mode. Computed frequency-of-transfer rates should be supported with data from endurance or reliability testing, in-service experience on similar equipment, or other appropriate data.
- The magnitude of the power, thrust, rotor or Propeller speed transients.
- Successful demonstration, by simulation or other means, of the ability of the Engine Control System to control the Engine safely during the transition. In some cases, particularly those involving rotorcraft, it may not be possible to make a determination that the mode transition provides a safe system based solely on analytical or simulation data. Therefore, a flight test programme to support this data will normally be expected.
- An analysis should be provided to identify those Faults that cause Control Mode transitions either automatically or through pilot action.
- For turboprop or turboshaft engines, the transition should not result in excessive over-speed or under-speed of the rotor or Propeller which could cause emergency shutdown, loss of electrical generator power or the setting-off of warning devices.

The power or thrust change associated with the transition should be declared in the instructions for installing the Engine.

(i) Time Delays

Any observable time delays associated with Control Mode, channel or system transitions or in re-establishing the pilot's ability to modulate Engine thrust or power should be identified in the Engine instructions for installation and operation (see CS-E 50 (b)). These delays should be assessed during aircraft certification.

(ii) Annunciation to the Flight Crew

If annunciation is necessary to comply with CS-E 50(b)(3), the type of annunciation to the flight crew should be commensurate with the nature of the transition. For instance, reversion to an Alternate Mode of control where the transition is automatic and the only observable changes in operation of the Engine are different thrust control schedules, would require a very different form of annunciation to that required if timely action by the pilot is required in order to maintain control of the aircraft.

The intent and purpose of the cockpit annunciation should be clearly stated in the Engine instructions for installation and operation, as appropriate.

(e) Environmental conditions

Environmental conditions include EMI, HIRF and lightning. The environmental conditions are addressed under CS E-80 and CS-E 170. The following provides additional guidance for EMI, HIRF and lightning.

(i) Declared levels

When the installation is known during the Engine type certification programme, the Engine Control System should be tested at levels that have been determined and agreed by the Engine and aircraft applicants. It is assumed that, by this agreement, the installation can meet the aircraft certification specifications. Successful completion of the testing to the agreed levels would be accepted for Engine type certification. This, however, may make the possibility of installing the Engine dependent on a specific aircraft.

If the aircraft installation is not known or defined at the time of the Engine certification, in order to determine the levels to be declared for the Engine certification, the Engine applicant may use the external threat level defined at the aircraft level and use assumptions on installation attenuation effects.

If none of the options defined above are available, it is recommended that the procedures and minimum default levels for HIRF testing are agreed with the Agency.

(ii) Test procedures

(A) General

The installed Engine Control System, including representative Engine-aircraft interface cables, should be the basis for certification testing.

Electro-Magnetic Interference (EMI) test procedures and test levels conducted in accordance with MIL-STD-461 or EUROCAE ED 14/DO-160 have been considered acceptable.

The applicant should use the HIRF test guidelines provided in EUROCAE ED 14/RTCA DO-160 or equivalent. However, it should be recognised that the tests defined in EUROCAE ED 14/RTCA DO-160 are applicable at a component test level, requiring the applicant to adapt these test procedures to a system level HIRF test to demonstrate compliance with CS-E 80 and CS-E 170.

For lightning tests, the guidelines of SAE ARP 5412, 5413, 5414, and 5416 and EUROCAE ED 14/RTCA DO-160 would be applicable.

Pin Injection Tests (PIT) are normally conducted as component tests on the EECS unit and other system components as required. PIT levels are selected as appropriate from the tables of EUROCAE ED 14/DO-160.

Environmental tests such as MIL-STD-810 may be accepted in lieu of EUROCAE ED-14/DO-160 tests where these tests are equal to or more rigorous than those defined in EUROCAE ED 14/DO-160.

(B) Open loop and Closed loop Testing

HIRF and lightning tests should be conducted as system tests on closed loop or open loop laboratory set-ups.

The closed loop set-up is usually provided with hydraulic pressure to move actuators to close the inner actuating loops. A simplified Engine simulation may be used to close the outer Engine loop.

Testing should be conducted with the Engine Control System controlling at the most sensitive operating point, as selected and detailed in the test plans by the applicant. The system should be exposed to the HIRF and lightning environmental threats while operating at the selected condition. There may be a different operating point for HIRF and lightning environmental threats.

For tests in open and closed loop set ups, the following factors should also be considered:

- If special EECS test software is used, that software should be developed and implemented by guidelines defined for software levels of at least software level C as defined in the industry documents referred in the latest edition of AMC 20-115. In some cases, the application code is modified to include the required test code features.

- The system test set-up should be capable of monitoring both the output drive signals and the input signals.
- Anomalies observed during open loop testing on inputs or outputs should be duplicated on the Engine simulation to determine whether the resulting power or thrust perturbations comply with the pass/fail criteria.

(iii) Pass/Fail Criteria

The pass/fail criteria of CS-E 170 for HIRF and lightning should be interpreted as 'no adverse effect' on the functionality of the system.

The following are considered adverse effects:

- A greater than 3 % change of Take-off Power or Thrust for a period of more than two seconds.
- Transfers to alternate channels, Back-up Systems, or Alternate Modes.
- Component damage.
- False annunciation to the crew which could cause unnecessary or inappropriate crew action.
- Erroneous operation of protection systems, such as over-speed or thrust reverser circuits.

Hardware or Software design changes implemented after initial environmental testing should be evaluated for their effects with respect to the EMI, HIRF and lightning environment.

(iv) Maintenance Actions

CS-E 25 requires that the applicant prepare Instructions for Continued Airworthiness (ICA). This includes a maintenance plan. Therefore, for any protection system that is part of the type design of the Engine Control System and is required by the system to meet the qualified levels of EMI, HIRF and lightning, a maintenance plan should be provided to ensure the continued airworthiness for the parts of the installed system which are supplied by the Engine type certificate holder.

.The maintenance actions to be considered include periodic inspections or tests for required structural shielding, wire shields, connectors, and equipment protection components. Inspections or tests when the part is exposed may also be considered. The applicant should provide the engineering validation and substantiation of these maintenance actions.

(v) Time Limited Dispatch (TLD) Environmental Tests

Although TLD is only an optional requirement for certification (see CS-E 1000 and CS-E 1030), EMI, HIRF and lightning tests for TLD are usually conducted together with tests conducted for certification. Acceptable means of compliance are provided in AMC E 1030.

(7) INTEGRITY OF THE ENGINE CONTROL SYSTEM

(a) Objective

The intent of CS-E 50 (c) is to establish Engine Control System integrity requirements consistent with operational requirements of the various installations. (See also paragraph (4) of AMC E 50).

(b) Definition of an LOTC/LOPC event

(i) For turbine Engines intended for CS-25 installations

An LOTC/LOPC event is defined as an event where the Engine Control System:

- has lost the capability of modulating thrust or power between idle and 90 % of maximum rated power or thrust, or
- suffers a Fault which results in a thrust or power oscillation greater than the levels given in paragraph (7)(c) of this AMC, or

- has lost the capability to govern the Engine in a manner which allows compliance with the operability specifications given in CS-E 500 (a) and CS-E 745.

(ii) For turbine Engines intended for rotorcraft

An LOPC event is defined as an event where the Engine Control System:

- has lost the capability of modulating power between idle and 90 % of maximum rated power at the flight condition, except OEI power ratings, or
- suffers a Fault which results in a power oscillation greater than the levels given in paragraph (7)(c) of this AMC, or
- has lost the capability to govern the Engine in a manner which allows compliance with the operability specifications given in CS-E 500 (a) and CS-E 745, with the exception that the inability to meet the operability specifications in the Alternate Modes may not be included as LOPC events.
- Single Engine rotorcraft will be required to meet the operability specifications in the Alternate Mode(s), unless the lack of this capability is demonstrated to be acceptable at the aircraft level. Engine operability in the Alternate Mode(s) is considered a necessity if:
- the control transitions to the Alternate Mode more frequently than the acceptable LOPC rate, or
- normal flight crew activity requires rapid changes in power to safely fly the aircraft.
- For multi-Engine rotorcraft, the LOPC definition may not need to include the inability to meet the operability specifications in the Alternate Mode(s). This may be considered acceptable because when one Engine control transitions to an Alternate Mode, which may not have robust operability, that Engine can be left at reasonably fixed power conditions. The Engine(s) with the normally operating control(s) can change power – as necessary – to complete aircraft manoeuvres and safely land the aircraft. Demonstration of the acceptability of this type of operation may be required at aircraft certification.

(iii) For turbine Engines intended for other installations

A LOTC/LOPC event is defined as an event where the Engine Control System:

- has lost the capability of modulating thrust or power between idle and 90 % of maximum rated power or thrust, or
- suffers a Fault which results in a thrust or power oscillation that would impact controllability in the intended installation, or
- has lost the capability to govern the Engine in a manner which allows compliance with the operability specifications given in CS-E 500 (a) and CS-E 745, as appropriate.

(iv) For piston Engines

An LOPC event is defined as an event where the Engine Control System:

- has lost the capability of modulating power between idle and 85 % of maximum rated power at all operating conditions, or
- suffers a Fault which results in a power oscillation greater than the levels given in paragraph (7)(c) of this AMC, or
- has lost the capability to govern the Engine in a manner which allows compliance with the operability specifications given in CS-E 390.

(v) For engines incorporating functions for Propeller control integrated in the EECS

The following Faults or Failures should be considered as additional LOPC events:

- inability to command a change in pitch,

- uncommanded change in pitch,
- uncontrollable Propeller torque or speed fluctuation.

(c) Uncommanded thrust or power oscillations

Any uncommanded thrust or power oscillations should be of such a magnitude as not to impact aircraft controllability in the intended installation. Thrust or power oscillations less than 10 % peak to peak of Take-off Power and/or Thrust have been considered acceptable in some installations, where the failure affects one engine only. Regardless of the levels discussed herein, if the flight crew has to shut down an Engine because of unacceptable thrust or power oscillations caused by the control system, such an event would be deemed an in-service LOTC/LOPC event.

(d) Acceptable LOTC/LOPC rate

The applicant may propose an LOTC/LOPC rate other than those below. Such a proposal should be substantiated in relation to the criticality of the Engine and control system relative to the intended installation. The intent is to show equivalence of the LOTC/LOPC rate to existing systems in comparable installations.

(i) For turbine Engines

The EECS should not cause more than one LOTC/LOPC event per 100 000 engine flight hours.

(ii) For piston Engines

An LOPC rate of 45 per million engine flight hours (or 1 per 22,222 engine flight hours) has been shown to represent an acceptable level for the most complex EECS. As a result of the architectures used in many of the EECS for these engines, the functions are implemented in independent system elements. These system elements or sub-systems can be fuel control, or ignition control, or others. If a system were to contain only one element such as fuel control, then the appropriate total system level would be 15 LOPC events per million engine flight hours. So the system elements are then additive up to a max of 45 LOPC events per million hours. For example, an EEC system comprised of fuel, ignition, and wastegate control functions should meet a total system reliability of 15+15+15 = 45 LOPC events per million engine flight hours. This criterion is then applied to the entire system and not allocated to each of the subsystems. Note that a maximum of 45 LOPC events per million engine flight hours are allowed, regardless of the number of subsystems. For example, if the EEC system includes more than three subsystems, the sum of the LOPC rates for the total system should not exceed 45 LOPC events per million engine flight hours for all of the electrical and electronic elements.

(e) LOTC/LOPC Analysis

A system reliability analysis should be submitted to substantiate the agreed LOTC/LOPC rate for the Engine Control System. A numerical analysis such as a Markov model analysis, fault tree analysis or equivalent analytical approach is expected.

The analysis should address all components in the system that can contribute to LOTC/LOPC events. This includes all electrical, mechanical, hydromechanical, and pneumatic elements of the Engine Control System. This LOTC/LOPC analysis should be done in conjunction with the System Safety Assessment required under CS-E 50 (d). Paragraph (8) of this AMC provides additional guidance material.

The engine fuel pump is generally not included in the definition of the Engine Control System. It is usually considered part of the fuel delivery system.

The LOTC/LOPC analysis should include those sensors or elements which may not be part of the Engine type design, but which may contribute to LOTC/LOPC events. An example of this is the throttle or power lever transducer, which is usually supplied by the installer. The effects of loss, corruption or Failure of Aircraft-Supplied Data should be included in the Engine Control System's LOTC/LOPC analysis. The reliability and interface requirements for these non-Engine type design elements should be contained in the Engine instructions for installation. It needs to be ensured that there is no double counting of the rate of Failure of non-engine parts within the aircraft system safety analyses.

The LOTC/LOPC analysis should consider all Faults, both detected and undetected. Any periodic maintenance actions needed to find and repair both Covered and Uncovered Faults, in order to meet the LOTC/LOPC rate, should be contained in the Engine instructions for continued airworthiness.

(f) Commercial or Industrial Grade Electronic Parts

When the Engine type design specifies commercial or industrial grade electronic components, which are parts not manufactured to military standards, the applicant should have the following data available for review, as applicable:

- Reliability data that substantiates the Failure rate for each component used in the LOTC/LOPC analysis and the SSA for each commercial and industrial grade electrical component specified in the design.
- The applicant's procurement, quality assurance, and process control plans for the vendor-supplied commercial and industrial grade parts. These plans should ensure that the parts will be able to maintain the reliability level specified in the approved Engine type design.
- Unique databases for similar components obtained from different vendors, because commercial and industrial grade parts may not all be manufactured to the same accepted industry standard, such as military component standards.
- Commercial and industrial grade parts have typical operating ranges of 0 degrees to +70 degrees Celsius and -40 degrees to +85 degrees Celsius, respectively. Military grade parts are typically rated at -54 degrees to 125 degrees Celsius. Commercial and industrial grade parts are typically defined in these temperature ranges in vendor parts catalogues. If the declared temperature environment for the Engine Control System exceeds the stated capability of the commercial or industrial grade electronic components, the applicant should substantiate that the proposed extended range of the specified components is suitable for the installation and that the Failure rates used for those components in the SSA and LOTC/LOPC analyses is appropriately adjusted for the extended temperature environment. Additionally, if commercial or industrial parts are used in an environment beyond their specified rating and cooling provisions are required in the design of the EECS, the applicant should specify these provisions in the instructions for installation to ensure that the provisions for cooling are not compromised. . Failure modes of the cooling provisions included in the EECS design that cause these limits to be exceeded should be considered in determining the probability of Failure.
- Two examples of industry published documents which provide guidance on the application of commercial or industrial grade components are:
  - IEC/PAS 62239, Electronic Component Management Plans
  - IEC/PAS 62240, Use of Semiconductor Devices Outside Manufacturers' Specified Temperature Ranges

When any electrical or electronic components are changed, the SSA and LOTC/LOPC analyses should be reviewed with regard to the impact of any changes in component reliability. Component, subassembly or assembly level testing may be required by the Agency to substantiate a change that introduces a commercial or industrial part(s). However, such a change would not be classified as 'significant' with respect to Part 21A.101(b)1.

(g) Single Fault Accommodation

Compliance with the single Fault specifications of CS-E 50 (c)(2) and (3) may be substantiated by a combination of tests and analyses. The intent is that single Failures or malfunctions in the Engine Control System's components, in its fully operational condition, do not result in a Hazardous Engine Effect. In addition, in its full-up configuration the control system should be essentially single Fault tolerant of electrical/electronic component Failures with respect to LOTC/LOPC events. For dispatchable configurations refer to CS-E 1030 and AMC E 1030.

It is recognised that to achieve true single Fault tolerance for LOTC/LOPC events could require a triplicated design approach or a design approach with 100 % Fault detection. Currently, systems have been designed with dual, redundant channels or with Back-up Systems that provide what has been called an 'essentially single Fault tolerant' system. Although these systems may have some Faults that are not Covered Faults, they have demonstrated excellent in-service safety and reliability, and have proven to be acceptable.

The objective, of course, is to have all the Faults addressed as Covered Faults. Indeed, the dual channel or Back-up system configurations do cover the vast majority of potential electrical and electronic Faults. However, on a case-by-case basis, it may be appropriate for the applicant to omit some coverage because detection or accommodation of some electrical/electronic Faults may not be practical. In these cases, it is recognised that single, simple electrical or electronic components or circuits can be employed in a reliable manner, and that requiring redundancy in some situations may not be appropriate. In these circumstances, Failures in some single electrical or electronic components, elements or circuits may result in an LOTC/LOPC event. This is what is meant by the use of the term 'essentially', and such a system may be acceptable.

(h) Local Events

Examples of local events to be considered under CS-E 50 (c)(4) include:

- Overheat conditions, for example, those resulting from hot air duct bursts,
- Fires, and
- Fluid leaks or mechanical disruptions which could lead to damage to control system electrical harnesses, connectors, or the control unit(s).

These local events would normally be limited to one Engine. Therefore, a local event is not usually considered to be a common mode event, and common mode threats, such as HIRF, lightning and rain, are not considered local events.

When demonstration that there is no Hazardous Engine Effect is based on the assumption that another function exists to afford the necessary protection, it should be shown that this function is not rendered inoperative by the same local event on the Engine (including destruction of wires, ducts, power supplies).

It is considered that an overheat condition exists when the temperature of the system components is greater than the maximum safe design operating temperature for the components, as declared by the Engine applicant in the Engine instructions for installation. The Engine Control System should not cause a Hazardous Engine Effect when the components or units of the system are exposed to an overheat or over-temperature condition. Specific design features or analysis methods may be used to show compliance with respect to the prevention of Hazardous Engine Effects. Where this is not possible, for example, due to the variability or the complexity of the Failure sequence, then testing may be required.

The Engine Control System, including the electrical, electronic and mechanical parts of the system, should comply with the fire specifications of CS-E 130 and the interpretative material of AMC E 130 is relevant. This rule applies to the elements of the Engine Control System which are installed in designated fire zones.

There is no probability associated with CS-E 50 (c)(4). Hence, all foreseeable local events should be considered. It is recognised, however, that it is difficult to address all possible local events in the intended aircraft installation at the time of Engine certification. Therefore, sound Engineering judgement should be applied in order to identify the reasonably foreseeable local events. Compliance with this specification may be shown by considering the end result of the local event on the Engine Control System. The local events analysed should be well documented to aid in certification of the Engine installation.

The following guidance applies to Engine Control System wiring:

- Each wire or combination of wires interfacing with the EECS that could be affected by a local event should be tested or analysed with respect to local events. The assessment should include opens, shorts to ground and shorts to power (when appropriate) and the results should show that Faults result in identified responses and do not result in Hazardous Engine Effects.

- Engine control unit aircraft interface wiring should be tested or analysed for shorts to aircraft power, and these 'hot' shorts should result in an identified and non-Hazardous Engine Effect. Where aircraft interface wiring is involved, the installer should be informed of the potential effects of interface wiring Faults by means of information provided in the Engine instructions for installation. It is the installer's responsibility to ensure that there are no wiring Faults which could affect more than one Engine. Where practical, wiring Faults should not affect more than one channel. Any assumptions made by the Engine applicant regarding channel separation should be included in the LOTC/LOPC analysis.
- Where physical separation of conductors is not practical, co-ordination between the Engine applicant and the installer should ensure that the potential for common mode Faults between Engine Control Systems is eliminated, and between channels on one Engine is minimised.

The applicant should assess by analysis or test the effects of fluid leaks impinging on components of the Electronic Engine Control System. Such conditions should not result in a Hazardous Engine Effect, nor should the fluids be allowed to impinge on circuitry or printed circuit boards and result in a potential latent Failure condition.

(8) SYSTEM SAFETY ASSESSMENT

(a) Scope of the assessment

The system safety assessment (SSA) required under CS-E 50 (d) should address all operating modes, and the data used in the SSA should be substantiated.

The LOTC/LOPC analysis described in Section 7 is a subset of the SSA. The LOTC/LOPC analysis and SSA may be separate or combined as a single analysis.

The SSA should consider all Faults, both detected and undetected, and their effects on the Engine Control System and the Engine itself. The intent is primarily to address the Faults or malfunctions which only affect one Engine Control System, and therefore only one Engine. However, Faults or malfunctions in aircraft signals, including those in a multi-engine installation that could affect more than one Engine, should also be included in the SSA; these types of Faults are addressed under CS-E 50 (g).

The Engine Control System SSA and LOTC/LOPC analysis, or combined analyses, should identify the applicable assumptions and installation requirements and establish any limitations relating to Engine Control System operation. These assumptions, requirements, and limitations should be stated in the Engine instructions for installation and operation as appropriate. If necessary, the limitations should be contained in the airworthiness limitations section of the instructions for continued airworthiness in accordance with CS-E 25 (b)(1).

The SSA should address all Failure effects identified under CS-E 510 or CS-E 210, as appropriate. A summary should be provided, listing the malfunctions or Failures and their effects caused by the Engine Control System, such as:

- Failures affecting power or thrust resulting in LOTC/LOPC events.
- Failures which result in the Engine's inability to meet the operability specifications. If these Failure cases are not considered as LOPC events according to paragraph (7)(b)(ii) of this AMC, the expected frequency of occurrence for these events should be documented.
- Transmission of erroneous parameters which could lead to thrust or power changes greater than 3 % of Take-off Power or Thrust (10 % for piston engines installations) (e.g., false high indication of the thrust or power setting parameter) or to Engine shutdown (e.g., high EGT or turbine temperatures or low oil pressure).
- Failures affecting functions included in the Engine Control System, which may be considered aircraft functions (e.g. Propeller control, thrust reverser control, control of cooling air, control of fuel recirculation)
- Failures resulting in Major Engine Effects and Hazardous Engine Effects.

The SSA should also consider all signals used by the Engine Control System, in particular any cross-Engine control signals and air signals as described in CS-E 50 (i).

The criticality of functions included in the Engine Control System for aircraft level functions needs to be defined by the aircraft applicant.

(b) Criteria

The SSA should demonstrate or provide the following:

(i) Compliance with CS-E 510 or CS-E 210, as appropriate.

(ii) For Failures leading to LOTC/LOPC events,

compliance with the agreed LOTC/LOPC rate for the intended installation (see paragraph (7)(d) of this AMC).

(iii) For Failures affecting Engine operability but not leading to LOPC events,

compliance with the expected total frequency of occurrence of Failures that result in Engine response that is non-compliant with CS-E 390, CS-E 500 (a) and CS-E 745 specifications (as appropriate). The acceptability of the frequency of occurrence for these events - along with any aircraft flight deck indications deemed necessary to inform the flight crew of such a condition - will be determined at aircraft certification.

(iv) The consequence of the transmission of a faulty parameter

The consequence of the transmission of a faulty parameter by the Engine Control System should be identified and included, as appropriate, in the LOTC/LOPC analysis. Any information necessary to mitigate the consequence of a faulty parameter transmission should be contained in the Engine operating instructions.

For example, the Engine operating instructions may indicate that a display of zero oil pressure be ignored in-flight if the oil quantity and temperature displays appear normal. In this situation, Failure to transmit oil pressure or transmitting a zero oil pressure signal should not lead to an Engine shutdown or LOTC/LOPC event. Admittedly, flight crew initiated shutdowns have occurred in-service during such conditions. In this regard, if the Engine operating instructions provide information to mitigate the condition, then control system Faults or malfunctions leading to the condition do not have to be included in the LOTC/LOPC analysis. In such a situation, the loss of multiple functions should be included in the LOTC/LOPC analysis. If the display of zero oil pressure and zero oil quantity (or high oil temperature) would result in a crew initiated shutdown, then those conditions should be included in the systems LOTC/LOPC analysis.

(c) Malfunctions or Faults affecting thrust or power

In multi-engine aeroplanes, Faults that result in thrust or power changes of less than approximately 10 % of Take-off Power or Thrust may be undetectable by the flight crew. This level is based on pilot assessment and has been in use for a number of years. The pilots indicated that flight crews will note the Engine operating differences when the difference is greater than 10 % in asymmetric thrust or power.

The detectable difference level for Engines for other installations should be agreed with the installer.

When operating in the take-off envelope, Uncovered Faults in the Engine Control System which result in a thrust or power change of less than 3 % (10 % for piston engines installations), are generally considered acceptable. However, this does not detract from the applicant's obligation to ensure that the full-up system is capable of providing the declared minimum rated thrust or power. In this regard, Faults which could result in small thrust changes should be random in nature and detectable and correctable during routine inspections, overhauls or power-checks.

The frequency of occurrence of Uncovered Faults that result in a thrust or power change greater than 3 % of Take-off Power or Thrust , but less than the change defined as an LOTC/LOPC event, should be contained in the SSA documentation. There are no firm specifications relating to this class of Faults for Engine certification; however the rate of occurrence of these types of Faults should be reasonably low, in the order of 10^{-4} events per Engine flight hour or less. These Faults may be required to be included in aircraft certification analysis.

Signals sent from one Engine Control System to another in an aeroplane installation, such as signals used for an Automatic Take-off Thrust Control System (ATTCS), synchrophasing, etc., are addressed under CS-E 50 (g). They should be limited in authority by the receiving Engine Control System, so that undetected Faults do not result in an unacceptable change in thrust or power on the Engine using those signals. The maximum thrust or power loss on the Engine using a cross-Engine signal should generally be limited to 3 % absolute difference of the current operating condition.

Note: It is recognised that ATTCS, when activated, may command a thrust or power increase of 10 % or more on the remaining Engine(s). It is also recognised that signals sent from one Engine control to another in a rotorcraft installation, such as load sharing and One Engine Inoperative (OEI), can have a much greater impact on Engine power when those signals fail. Data of these Failure modes should be contained in the SSA.

When operating in the take-off envelope, detected Faults in the Engine Control System, which result in a thrust or power change of up to 10 % (15 % for piston engines) may be acceptable if the total frequency of occurrence for these types of Failures is relatively low. The predicted frequency of occurrence for this category of Faults should be contained in SSA documentation. It should be noted that requirements for the allowable frequency of occurrence for this category of Faults and any need for a flight deck indication of these conditions would be reviewed during aircraft certification. A total frequency of occurrence in excess of 10^{-4} events per Engine flight hour would not normally be acceptable.

Detected Faults in signals exchanged between Engine Control Systems should be accommodated so as not to result in greater than a 3 % thrust or power change on the Engine using the cross-Engine signals.

(9) PROTECTIVE FUNCTIONS

(a) Rotor Over-speed Protection.

Rotor over-speed protection is usually achieved by providing an independent over-speed protection system, such that it requires two independent Faults or malfunctions (as described below) to result in an uncontrolled over-speed.

The following guidance applies if the rotor over-speed protection is provided solely by an Engine Control System protective function.

For dispatchable configurations, refer to CS-E 1030 and AMC E 1030.

The SSA should show that the probability per Engine flight hour of an uncontrolled over-speed condition from any cause in combination with a Failure of the over-speed protection system to function is less than one event per hundred million hours (a Failure rate of 10^{-8} events per Engine flight hour).

The over-speed protection system would be expected to have a Failure rate of less than 10^{-4} Failures per engine flight hour to ensure the integrity of the protected function.

A self-test of the over-speed protection system to ensure its functionality prior to each flight is normally necessary for achieving the objectives. Verifying the functionality of the over-speed protection system at Engine shutdown and/or start-up is considered adequate for compliance with this requirement. It is recognised that some Engines may routinely not be shut down between flight cycles. In this case this should be accounted for in the analyses.

Because in some over-speed protection systems there are multiple protection paths, there will always be uncertainty that all paths are functional at any given time. Where multiple paths can invoke the over-speed protection system, a test of a different path may be performed each Engine cycle. The objective is that a complete test of the over-speed system, including electro-mechanical parts, is achieved in the minimum number of Engine cycles. This is acceptable so long as the system meets a 10^{-4} Failure rate.

The applicant may provide data that demonstrates that the mechanical parts (this does not include the electro-mechanical parts) of the over-speed protection system can operate without Failure between stated periods, and a periodic inspection may be established for those parts. This data is acceptable in lieu of testing the mechanical parts of the sub-system each Engine cycle.

(b) Other protective functions

The Engine Control System may perform other protective functions. Some of these may be Engine functions, but others may be aircraft or Propeller functions. Engine functions should be considered under the guidelines of this AMC. The integrity of other protective functions provided by the Engine Control System should be consistent with a safety analysis associated with those functions, but if those functions are not Engine functions, they may not be a part of Engine certification.

As Engine Control Systems become increasingly integrated into the aircraft and Propeller systems, they are incorporating protective functions that were previously provided by the aircraft or Propeller systems. Examples are reducing the Engine to idle thrust if a thrust reverser deploys and providing the auto-feather function for the Propeller when an Engine fails.

The reliability and availability associated with these functions should be consistent with the top level hazard assessment of conditions involving these functions. This will be completed during aircraft certification.

For example, if an Engine Failure with loss of the auto-feather function is catastrophic at the aircraft level - and the auto-feather function is incorporated into the Engine Control System - the applicant will have to show for CS-25 installations (or CS-23 installations certified to CS-25 specifications) that an Engine Failure with loss of the auto-feather function cannot result from a single control system Failure, and that combinations of control system Failures, or Engine and control system Failures, which lead to a significant Engine loss of thrust or power with an associated loss of the autofeather function may be required to have an extremely improbable event rate (i.e., 10^{-9} events per Engine flight hour).

Although these functions await evaluation at the aircraft level, it is strongly recommended that, if practicable, the aircraft level hazard assessment involving these functions be available at the time of the Engine Control System certification. This will facilitate discussions and co-ordination between the Engine and aircraft certification teams under the conditions outlined in paragraph (15) of this AMC. It is recognised that this co-ordination may not occur for various reasons. Because of this, the applicant should recognise that although the Engine may be certified, it may not be installable at the aircraft level.

The overall requirement is that the safety assessment of the Engine Control System should include all Failure modes of all functions incorporated in the system. This includes those functions which are added to support aircraft certification, so that the information of those Failure modes will get properly addressed and passed on to the installer for inclusion in the airframe SSA. Information concerning the frequencies of occurrence of those Failure modes may be needed as well.

(10) SOFTWARE DESIGN AND IMPLEMENTATION

(a) Objective

For Engine Control Systems that use software, the objective of CS-E 50 (f) is to prevent as far as possible software errors that would result in an unacceptable effect on power or thrust, or any unsafe condition.

It is understood that it may be impossible to establish with certainty that the software has been designed without errors. However, if the applicant uses the software level appropriate for the criticality of the performed functions and uses approved software development and verification processes, the Agency would consider the software to be compliant with the requirement to minimise errors. In multiple Engine installations, the possibility of software errors common to more than one Engine Control System may determine the criticality level of the software.

(b) Approved Methods

Methods for developing software, compliant with the guidelines contained in the latest edition of AMC 20-115 are acceptable methods. Alternative methods for developing software may be proposed by the applicant and are subject to approval by the Agency.

Software which was not developed using the version of ED-12 referenced in the latest edition of AMC 20-115 is referred to as legacy software. In general, changes made to legacy software applicable to its original installation are assured in the same manner as the original certification. When legacy software is used in a new aircraft installation that requires the latest edition of AMC 20-115, the original approval of the legacy software is still valid, assuming equivalence to the required software level can be ascertained. If the software equivalence is acceptable to the Agency taking into account the conditions defined the latest edition of AMC 20-115, the legacy software can be used in the new installation that requires AMC 20-115 software. If equivalence cannot be substantiated, all the software changes should be assured through the use of the latest edition of AMC 20-115.

(c) Level of software design assurance

In multiple Engine installations, the design, implementation and verification of the software in accordance with Level A (as defined in the industry documents referred in the latest edition of AMC 20-115) is normally needed to achieve the certification objectives for aircraft to be type certificated under CS-25, CS-27-Category A and CS-29-Category A.

The criticality of functions on other aircraft may be different, and therefore, a different level of software development assurance may be acceptable. For example, in the case of a piston engine in a single-engine aircraft, level C (as defined in the industry documents referred in the latest edition of AMC 20-115) software has been found to be acceptable.

Determination of the appropriate software level may depend on the Failure modes and consequences of those Failures. For example, it is possible that Failures resulting in significant thrust or power increases or oscillations may be more severe than an Engine shutdown, and therefore, the possibility of these types of Failures should be considered when selecting a given software level.

It may be possible to partition non-critical software from the critical software and design and implement the non-critical software to a lower level as defined by the industry documents referred in the latest edition of AMC 20-115. The adequacy of the partitioning method should be demonstrated. This demonstration should consider whether the partitioned lower software levels are appropriate for any anticipated installations. Should the criticality level be higher in subsequent installations, it would be difficult to raise the software level.

(d) On-Board or Field Software Loading and Part Number Marking

The following guidelines should be followed when on-board or field loading of Electronic Engine Control software and associated Electronic Part Marking (EPM) is implemented.

For software changes, the software to be loaded should have been documented by an approved design change and released with a service bulletin.

For an EECS unit having separate part numbers for hardware and software, the software part number(s) need not be displayed on the unit as long as the software part number(s) is(are) embedded in the loaded software and can be verified by electronic means. When new software is loaded into the unit, the same verification requirement applies and the proper software part number should be verified before the unit is returned to service.

For an EECS unit having only one part number, which represents a combination of a software and hardware build, the unit part number on the nameplate should be changed or updated when the new software is loaded. The software build or version number should be verified before the unit is returned to service.

The configuration control system for an EECS that will be onboard/field loaded and using electronic part marking should be approved. The drawing system should provide a compatibility table that tabulates the combinations of hardware part numbers and software versions that have been approved by the Agency. The top-level compatibility table should be under configuration control, and it should be updated for each change that affects hardware/software combinations. The applicable service bulletin should define the hardware configurations with which the new software version is compatible.

The loading system should be in compliance with the guidelines of the latest edition of AMC 20-115.

If the applicant proposes more than one source for loading, (e.g., diskette, mass storage, Secure Disk card, USB stick flash, etc.), all sources should comply with these guidelines.

The service bulletin should require verification that the correct software version has been loaded after installation on the aircraft.

(e) Software Change Category

The processes and methods used to change software should not affect the design software level of that software. For classification of software changes, refer to §4 in Appendix A of GM 21A.91.

(f) Software Changes by Others than the TC Holder

There are two types of potential software changes that could be implemented by someone other than the original TC holder:

- option-selectable software, or
- user-modifiable software (UMS).

Option-selectable changes would have to be pre-certified utilising a method of selection which has been shown not to be capable of causing a control malfunction.

UMS is software intended for modification by the aircraft operator without review by the certification authority, the aircraft applicant, or the equipment vendor. For Engine Control Systems, UMS has generally not been applicable. However, approval of UMS, if required, would be addressed on a case-by-case basis.

In principle, persons other than the TC holder may modify the software within the modification constraints defined by the TC holder, if the system has been certified with the provision for software user modifications. To certify an Electronic Engine Control System with the provision for software modification by others than the TC holder, the TC holder should (1) provide the necessary information for approval of the design and implementation of a software change, and (2) demonstrate that the necessary precautions have been taken to prevent the user modification from affecting Engine airworthiness, especially if the user modification is correctly implemented or not.

In the case where the software is changed in a manner not pre-allowed by the TC holder as ‘user modifiable’, the ‘non-TC holder’ applicant will have to comply with the requirements given in Part 21, subpart E.

(11) PROGRAMMABLE LOGIC DEVICES

CS-E 50 (f) applies to devices referred to as Programmable Logic Devices.

Because of the nature and complexity of systems containing digital logic, the Programmable Logic Devices should be developed using a structured development approach, commensurate with the hazard associated with Failure or malfunction of the system in which the device is contained.

RTCA DO-254/ EUROCAE ED-80 which describes the standards for the criticality and design assurance levels associated with Programmable Logic Devices development, is an acceptable means, but not the only means, for showing compliance with CS-E 50 (f).

For off-the-shelf equipment or modified equipment, service experience may be used in showing compliance to these standards. This should be acceptable provided the worst case Failure or malfunction of the device for the new installation is no more severe than that for original installation of the same equipment on another installation. Consideration should also be given to any significant differences related to environmental, operational or the category of the aircraft where the original system was installed and certified.

(12) AIRCRAFT-SUPPLIED DATA

(a) Objective

As required by CS-E 50 (g), in case of loss, interruption, or corruption of Aircraft-Supplied Data, the Engine should continue to function in a safe and acceptable manner, without unacceptable effects on thrust or power, Hazardous Engine Effects, or loss of ability to comply with the operating specifications of CS-E 390, CS-E 500 (a) and CS-E 745, as appropriate.

(b) Background

Historically, regulatory practice was to preserve the Engine independence from the aircraft. Hence even with very reliable architecture, such as triply redundant air data computer (ADC) systems, it was required that the Engine Control System provided an independent control means that could be used to safely fly the aircraft should all the ADC signals be lost.

However, with the increased Engine-aircraft integration that is currently occurring in the aviation industry and with the improvement in reliability and implementation of Aircraft-Supplied Data, the regulatory intent is being revised to require that Fault Accommodation be provided against single Failures of Aircraft-Supplied Data. This may include Fault Accommodation by transition into another Control Mode that is independent of Aircraft-Supplied Data.

The Engine Control System's LOTC/LOPC analysis should contain the effects of air data system Failures in all allowable Engine Control System and air data system dispatch configurations.

When Aircraft-Supplied Data can affect Engine Control System operation, the applicant should address the following items, as applicable, in the SSA or other appropriate documents:

- Software in the data path to the EECS should be at a level consistent with that defined for the EECS. The data path may include other aircraft equipment, such as aircraft thrust management computers, or other avionics equipment.
- The applicant should state in the instructions for installation that the aircraft applicant is responsible for ensuring that changes to aircraft equipment, including software, in the data path to the Engine do not affect the integrity of the data provided to the Engine as defined by the Engine instructions for installation.
- The applicant should supply the effects of faulty and corrupted Aircraft-Supplied Data on the EECS in the Engine instructions for installation.
- The instructions for installation should state that the installer should ensure that those sensors and equipment involved in delivering information to the EECS are capable of operating in the EMI, HIRF and lightning environments, as defined in the certification basis for the aircraft, without affecting their proper and continued operation.
- The applicant should state the reliability level for the Aircraft-Supplied Data that was used as part of the SSA and LOTC/LOPC analysis as an 'assumed value' in the instructions for installation.

As stated in CS-E 50 (g), thrust and power command signals sent from the aircraft are not subject to the specifications of CS-E 50 (g)(2). If the aircraft thrust or power command system is configured to move the Engine thrust or power levers or transmit an electronic signal to command a thrust or power change, the Engine Control System merely responds to the command and changes Engine thrust or power as appropriate. The Engine Control System may have no way of knowing that the sensed throttle or power lever movement was correct or erroneous.

In both the moving throttle (or power lever) and non-moving throttle (or power lever) configurations, it is the installer's responsibility to show that a proper functional hazard analysis is performed on the aircraft system involved in generating Engine thrust or power commands, and that the system meets the appropriate aircraft's functional hazard assessment safety related specifications. This task is an aircraft certification issue, however Failures of the system should be included in the Engine's LOTC/LOPC analysis.

(c) Design assessment

The applicant should prepare a Fault Accommodation chart that defines the Fault Accommodation architecture for the Aircraft-Supplied Data.

There may be elements of the Engine Control System that are mounted in the aircraft and are not part of the Engine type design, but which are dedicated to the Engine Control System and powered by it, such as a throttle position resolver. In these instances, such elements are considered to be an integral component of the Electronic Engine Control System and are not considered aircraft data.

In the case where the particular Failure modes of the aircraft air data may be unknown, the typical Failure modes of loss of data and erroneous data should be assumed. The term 'erroneous data' is used herein to describe a condition where the data appears to be valid but is incorrect.

Such assumptions and the results of the evaluation of erroneous aircraft data should be provided to the installer.

The following are examples of possible means of accommodation:

- Provision of an Alternate Mode that is independent of Aircraft-Supplied Data.
- Dual sources of aircraft-supplied sensor data with local Engine sensors provided as voters and alternate data sources.
- Use of synthesised Engine parameters to control or as voters. When synthesised parameters are used for control or voting purposes, the analysis should consider the impact of temperature and other environmental effects on those sensors whose data are used in the synthesis. The variability of any data or information necessary to relate the data from the sensors used in the synthesis to the parameters being synthesised should also be assessed.
- Triple redundant ADC systems that provide the required data.

If for aircraft certification it is intended to show that the complete loss of the aircraft air data system itself is extremely improbable, then it should be shown that the aircraft air data system is unaffected by a complete loss of aircraft generated power, for example, backed up by battery power. (See AMC 20-1)

(d) Effects on the Engine

CS-E 510 defines the Hazardous Engine Effects for turbine Engines.

CS-E 50 (g) is primarily intended to address the effects of aircraft signals, such as aircraft air data information, or other signals which could be common to all Engine Control Systems in a multi-Engine installation. The control system design should ensure that the full-up system is capable of providing the declared minimum rated thrust or power throughout the Engine operating envelope.

CS-E 50 (g) requires the applicant to provide an analysis of the effect of loss or corruption of aircraft data on Engine thrust or power. The effects of Failures in Aircraft-Supplied Data should be documented in the SSA as described in Section (8) above. Where appropriate, aircraft data Failures or malfunctions that contribute to LOTC/LOPC events should be included in the LOTC/LOPC analysis.

(e) Validation

Functionality of the Fault Accommodation logic should be demonstrated by test, analysis, or combination thereof. In the case where the aircraft air data system is not functional because of the loss of all aircraft generated power, the Engine Control System should include validated Fault Accommodation logic which allows the Engine to operate acceptably with the loss of all aircraft-supplied air data. Engine operation in this system configuration should be demonstrated by test.

For all dispatchable Control Modes, see CS-E 1030 and AMC E 1030.

If an Alternate Mode, independent of Aircraft-Supplied Data, has been provided to accommodate the loss of all data, sufficient testing should be conducted to demonstrate that the operability specifications have been met when operating in this mode. Characteristics of operation in this mode should be included in the instructions for installation and operation as appropriate. This Alternate Mode need not be dispatchable.

(13) AIRCRAFT SUPPLIED ELECTRICAL POWER

(a) Objective

The objective is to provide an electrical power source that is single Fault tolerant (including common cause or mode) in order to allow the EECS to comply with CS-E 50 (c)(2). The most common practice for achieving this objective has been to provide a dedicated electrical power source for the EECS. When aircraft electrical power is used, the assumed quality and reliability levels of this aircraft power should be contained in the instructions for installation.

(b) Electrical power sources

An Engine dedicated power source is defined herein as an electric power source providing electrical power generated and supplied solely for use by a single Engine Control System. Such a source is usually provided by an alternator(s), mechanically driven by the Engine or the transmission system of rotorcraft. However, with the increased integration of the Engine-aircraft systems and with the application of EECS to small Engines, both piston and turbine, use of an Engine-mounted alternator may not necessarily be the only design approach for meeting the objective.

Batteries are considered an Aircraft-Supplied Power source except in the case of piston Engines. For piston Engines, a battery source dedicated solely to the Engine Control System may be accepted as an Engine dedicated power source. In such applications, appropriate information for the installer should be provided including, for example, health status and maintenance requirements for the dedicated battery system.

(c) Analysis of the design architecture

An analysis and a review of the design architecture should identify the requirements for Engine dedicated power sources and Aircraft-Supplied Power sources. The analysis should include the effects of losing these sources. If the Engine is dependent on Aircraft-Supplied Power for any operational functions, the analysis should result in a definition of the requirements for Aircraft-Supplied Power.

The following configurations have been used:

- EECS dependent on Aircraft-Supplied Power
- EECS independent of Aircraft-Supplied Power (Engine dedicated power source)
- Aircraft-Supplied Power used for functions, switched by the EECS
- Aircraft-Supplied Power directly used for Engine functions, independently from the EECS
- Aircraft-Supplied Power used to back up the Engine dedicated power source

The capacity of any Engine dedicated power source, required to comply with CS-E 50 (h)(2), should provide sufficient margin to maintain confidence that the Engine Control System will continue to function in all anticipated Engine operating conditions where the control system is designed and expected to recover Engine operation automatically in-flight. The autonomy of the Engine Control System should be sufficient to ensure its functioning in the case of immediate automatic relight after unintended shutdown. Conversely, the autonomy of the Engine Control System in the whole envelope of restart in windmilling conditions is not always required. This margin should account for any other anticipated variations in the output of the dedicated power source such as those due to temperature variations, manufacturing tolerances and idle speed variations. The design margin should be substantiated by test and/or analysis and should also take into account any deterioration over the life of the Engine.

(d) Aircraft-Supplied Power Reliability

Any Aircraft-Supplied Power reliability values used in system analyses, whether supplied by the aircraft manufacturer or assumed, should be contained in the instructions for installation.

When Aircraft-Supplied Power is used in any architecture, if aircraft power Faults or Failures can contribute to LOTC/LOPC or Hazardous Engine Effects, these events should be included in the Engine SSA and LOTC/LOPC analyses.

When compliance with CS-E 50 (h)(1) imposes an Engine dedicated power source, Failure of this source should be addressed in the LOTC/LOPC analysis required under CS-E 50 (c). While no credit is normally necessary to be given in the LOTC/LOPC analysis for the use of Aircraft-Supplied Power as a back-up power source, Aircraft-Supplied Power has typically been provided for the purpose of accommodating the loss of the Engine dedicated power source. However, LOTC/LOPC allowance and any impact on the SSA for the use of Aircraft-Supplied Power as the sole power source for an Engine control Back-up System or as a back-up power source would be reviewed on a case-by-case basis.

In some system architectures, an Engine dedicated power source may not be required and Aircraft-Supplied Power may be acceptable as the sole source of power.

An example is a system that consists of a primary electronic single channel and a full capability hydromechanical Back-up System that is independent of electrical power (a full capability hydromechanical control system is one that meets all CS-E specifications and is not dependent on aircraft power). In this type of architecture, loss or interruption of Aircraft-Supplied Power is accommodated by transferring control to the hydromechanical system. Transition from the electronic to the hydromechanical control system is addressed under CS-E 50 (b).

Another example is an EECS powered by an aircraft power system that could support a critical fly-by-wire flight control system. Such a power system may be acceptable as the sole source of power for an EECS. In this example, it should be stated in the instructions for installation that a detailed design review and safety analysis is to be conducted to identify latent failures and common cause failures that could result in the loss of all electrical power. The instructions should also state that any emergency power sources must be known to be operational at the beginning of the flight. Any emergency power sources must be isolated from the normal electrical power system in such a way that the emergency power system will be available no matter what happens to the normal generated power system. If batteries are the source of emergency power, there must be a means of determining their condition prior to flight, and their capacity must be shown to be sufficient to assure exhaustion will not occur before getting the aircraft safely back on the ground.

This will satisfy that appropriate reliability assumptions are provided to the installer.

(e) Aircraft-Supplied Power Quality

When Aircraft-Supplied Power is necessary for operation of the Engine Control System, CS-E 50 (h)(3) specifies that the Engine instructions for installation contain the Engine Control System's electrical power supply quality requirements. This applies to any of the configurations listed in paragraph (13)(c) or any new configurations or novel approach not listed that use Aircraft-Supplied Power. These quality requirements should include steady state and transient under-voltage and over-voltage limits for the equipment. The power input standards of RTCA DO-160/EUROCAE ED-14 are considered to provide an acceptable definition of such requirements. If RTCA DO-160/EUROCAE ED-14 is used, any exceptions to the power quality standards cited for the particular category of equipment specified should be stated.

It is recognised that the electrical or electronic components of the Engine Control System when operated on Aircraft-Supplied Power may cease to operate during some low voltage aircraft power supply conditions beyond those required to sustain normal operation, but in no case should the operation of the Engine control result in a Hazardous Engine Effect. In addition, low voltage transients outside the control system's declared capability should not cause permanent loss of function of the control system, or result in inappropriate control system operation which could cause the Engine to exceed any operational limits, or cause the transmission of unacceptable erroneous data.

When aircraft power recovers from a low-voltage condition to a condition within which the control system is expected to operate normally, the Engine Control System should resume normal operation. The time interval associated with this recovery should be contained in the Engine instructions for installation. It is recognised that Aircraft-Supplied Power conditions may lead to an Engine shutdown or Engine condition which is not recoverable automatically. In these cases the Engine should be capable of being restarted, and any special flight crew procedures for executing an Engine restart during such conditions should be contained in the Engine instructions for operation. The acceptability of any non-recoverable Engine operating conditions - as a result of these Aircraft-Supplied Power conditions - will be determined at aircraft certification.

If Aircraft-Supplied Power supplied by a battery is required to meet an 'all Engines out' restart requirement, the analysis according to paragraph 13(c) should result in a definition of the requirements for this Aircraft-Supplied Power. In any installation where aircraft electrical power is used to operate the Engine Control System, such as low Engine speed in-flight re-starting conditions, the effects of any aircraft electrical bus-switching transients or power transients associated with application of electrical loads, which could cause an interruption in voltage or a decay in voltage below that level required for proper control functioning, should be considered.

(f) Effects on the Engine

Where loss of aircraft power results in a change in Engine Control Mode, the Control Mode transition should meet the specifications of CS-E 50 (b).

For some Engine control functions that rely exclusively upon Aircraft-Supplied Power, the loss of electrical power may still be acceptable. Acceptability is based on evaluation of the change in Engine operating characteristics, experience with similar designs, or the accommodation designed into the control system.

Examples of such Engine control functions that have traditionally been reliant on aircraft power include:

- Engine start and ignition
- Thrust Reverser deployment
- Anti-Icing (Engine probe heat)
- Fuel Shut-Off
- Over-speed Protection Systems
- Non-critical functions that are primarily performance enhancement functions which, if inoperative, do not affect the safe operation of the Engine.

(g) Validation

The applicant should demonstrate the effects of loss of Aircraft-Supplied Power by Engine test, system validation test or bench test or combination thereof.

(14) PISTON ENGINES

Piston Engines are addressed by the sections above; no additional specific guidance is necessary.

CS-E 50 specifications are applicable to these Engines but, when interpretation is necessary, the conditions which would be acceptable for the aircraft installation should be considered.

(15) ENGINE, PROPELLER AND AIRCRAFT SYSTEMS INTEGRATION AND INTER-RELATION BETWEEN ENGINE, PROPELLER AND AIRCRAFT CERTIFICATION ACTIVITIES

(a) Aircraft or Propeller Functions Integrated into the Engine Control System

This involves the integration of aircraft or Propeller functions (i.e., those that have traditionally not been considered Engine control functions), into the Electronic Engine Control System's hardware and software.

Examples of this include thrust reverser control systems, Propeller speed governors, which govern speed by varying pitch, and ATTCS. When this type of integration activity is pursued, the EECS becomes part of - and should be included in the aircraft's SSA, and although the aircraft functions incorporated into the EECS may receive review at Engine certification, the acceptability of the safety analysis involving these functions should be determined at aircraft certification.

The EECS may be configured to contain only part of the aircraft system's functionality, or it may contain virtually all of it. Thrust reverser control systems are an example where only part of the functionality is included in the EECS. In such cases, the aircraft is configured to have separate switches and logic (i.e., independent from the EECS) as part of the thrust reverser control system. This separation of reverser control system elements and logic provides an architectural means to limit the criticality of the functions provided by the EECS.

However, in some cases the EECS may be configured to incorporate virtually all of a critical aircraft function. Examples of this 'virtual completeness' in aircraft functionality are EECS which contain full authority to govern Propeller speed in turboprop powered aircraft and ATTCS in turbofan power aircraft.

The first of these examples is considered critical because, if an Engine fails, the logic in the Engine Control System should be configured to feather the Propeller on that Engine. Failure to rapidly feather the Propeller following an Engine Failure results in excessive drag on the aircraft, and such a condition can be critical to the aircraft. When functions like these are integrated into the Engine control such that they render an EECS critical, special attention should be paid to assuring that no single (including common cause/mode) Failures could cause the critical Failure condition, e.g. exposure of the EECS to overheat should not cause both an Engine shutdown and Failure of the Propeller to feather.

The second example, that of an ATTCS, is considered critical because the system is required to increase the thrust of the remaining Engine(s) following an Engine Failure during takeoff, and the increased thrust on the remaining Engines is necessary to achieve the required aircraft performance.

All of the above examples of integration involve aircraft functionality that would receive significant review during aircraft certification.

(b) Integration of Engine Control Functions into Aircraft Systems

The trend toward systems integration may lead to aircraft systems performing functions traditionally considered part of the Engine Control System. Some designs may use aircraft systems to implement a significant number of the Engine Control System functions. An example would be the complex integrated flight and Engine Control Systems – integrated in aircraft avionics units - which govern Engine speed, rotor speed, rotor pitch angle and rotor tilt angle in tilt-rotor aircraft.

In these designs, aircraft systems may be required to be used during Engine certification. In such cases, the Engine applicant is responsible for specifying the requirements for the EECS in the instructions for installation and substantiating the adequacy of those requirements.

An example of limited integration would be an Engine control which receives a torque output demand signal from the aircraft and responds by changing the Engine's fuel flow and other variables to meet that demand. However, the EECS itself, which is part of the type design, provides all the functionality required to safely operate the Engine in accordance with CS-E or other applicable specifications.

(c) Certification activities

(i) Objective

To satisfy the aircraft specifications, such as CS 25.901, CS 25.903 and CS 25.1309, an analysis of the consequences of Failures of the Engine Control System on the aircraft has to be made. The Engine applicant should, together with the aircraft applicant, ensure that the software levels and safety and reliability objectives for the Engine electronic control system are consistent with these specifications.

(ii) Interface Definition and System Responsibilities

System responsibilities as well as interface definitions should be identified for the functional and hardware and software aspects between the Engine, Propeller and the aircraft systems in the appropriate documents.

The Engine/Propeller/aircraft documents should cover in particular:

- Functional requirements and criticality (which may be based on Engine, Propeller and aircraft considerations)

- Fault Accommodation strategies
- Maintenance strategies
- The software level (per function if necessary),
- The reliability objectives for:
  - LOTC/LOPC events
  - Transmission of faulty parameters
- The environmental requirements including the degree of protection against lightning or other electromagnetic effects (e.g. level of induced voltages that can be supported at the interfaces)
- Engine, Propeller and aircraft interface data and characteristics
- Aircraft power supply requirements and characteristics (if relevant).

(iii) Distribution of Compliance Tasks

The tasks for the certification of the aircraft propulsion system equipped with Electronic Engine Control Systems may be shared between the Engine, Propeller and aircraft applicants. The distribution of these tasks between the applicants should be identified and agreed with the appropriate Engine, Propeller and aircraft authorities. For further information refer to AMC 20-1.

The aircraft certification should deal with the overall integration of the Engine and Propeller in compliance with the applicable aircraft specifications.

The Engine certification will address the functional aspects of the Engine Control System in compliance with the applicable Engine specifications.

Appropriate evidence provided for Engine certification should be used for aircraft certification. For example, the quality of any aircraft function software and aircraft/Engine interface logic already demonstrated for Engine certification should need no additional substantiation for aircraft certification.

Two examples are given below to illustrate this principle.

(A) Case of an EECS performing the functions for the control of the Engine and the functions for the control of the Propeller.

The Engine certification would address all general requirements such as software quality assurance procedures, EMI, HIRF and lightning protection levels, effects of loss of aircraft-supplied power.

The Engine certification would address the functional aspects for the Engine functions (safety analysis, rate for LOTC/LOPC events, effect of loss of Aircraft-Supplied Data, etc.). The Fault Accommodation logic affecting the control of the Engine, for example, will be reviewed at that time.

The Propeller certification will similarly address the functional aspects for the Propeller functions. The Fault Accommodation logic affecting the control of the Propeller, for example, will be reviewed at that time.

In this example, the Propeller functions and characteristics defined by the Propeller applicant, that are to be provided by the Engine Control System, would normally need to be refined by flight test. The Propeller applicant is responsible for ensuring that these functions and characteristics, that are provided for use during the Engine certification programme, define an airworthy Propeller configuration, even if they have not yet been refined by flight test.

With regard to changes in design, agreement by all parties involved should be reached so that changes to the Engine Control System that affect the Propeller system, or vice versa, do not lead to any inadvertent effects on the other system.

(B) *Case of an aircraft computer performing the functions for the control of the Engine.*

The aircraft certification will address all general requirements such as software quality assurance procedures, EMI, HIRF and lightning protection levels.

The aircraft certification will address the functional aspects for the aircraft functions.

The Engine certification will address the functional aspects for the Engine functions (safety analysis, rate for LOTC/LOPC events, effect of loss of Aircraft-Supplied Data, etc.) The Fault Accommodation logic affecting the control of the Engine, for example, will be reviewed at that time.

AMC 20-4A

Airworthiness Approval and Operational Criteria For the Use of Navigation Systems in European Airspace Designated For Basic RNAV Operations

This AMC presents Acceptable Means of Compliance relative to the implementation of Basic RNAV operations within European designated Airspace, from January 1998. This AMC has been co-ordinated with EUROCONTROL.

1 PURPOSE

This document provides acceptable means of compliance for airworthiness approval and operational criteria for the use of navigation systems in European airspace designated for Basic RNAV operations. The document establishes an acceptable means, but not the only means, that can be used in the airworthiness approval process, and provides guidelines for operators where GPS stand-alone equipment is used as the means for Basic RNAV operations. The document is in accordance with the April 1990 directive issued by the Transport Ministers of ECAC member states and with regard to the Basic RNAV operations as defined within the EUROCONTROL Standard 003-93 Edition 1 and satisfies the intent of ICAO Doc. 9613-AN/937 Manual on Required Navigation Performance (RNP) First Edition - 1994. It is consistent also with Regional Supplementary Procedures contained within ICAO Doc 7030.

2 SCOPE

This document provides guidance related to navigation systems intended to be used for Basic RNAV operations and considers existing airworthiness approval standards as providing acceptable means of compliance. The content is limited to general certification considerations including navigation performance, integrity, functional requirements and system limitations.

Compliance with the guidance in this Leaflet does not constitute an operational authorisation/approval to conduct Basic RNAV operations. Aircraft operators should apply to their Authority for such an authorisation/approval.

ICAO RNP-4 criteria are outside the scope of this AMC, but it is expected that navigation systems based on position updating from traditional radio aids and approved for Basic RNAV operations in accordance with this AMC will have an RNP-4 capability.

Related specifications

CS/FAR 25.1301, 25.1307, 25.1309, 25.1321, 25.1322, 25.1431

CS/FAR 23.1301, 23.1309, 23.1311, 23.1321, 23.1322, 23.1431

CS/FAR 27.1301, 27.1309, 27.1321, 27.1322

CS/FAR 29.1301, 29.1309, 29.1321, 29.1322, 29.1431

operating requirements

ATC Documents

EUROCONTROL Standard Document 003-93 Edition 1

ICAO Doc. 9613-AN/937 - Manual on Required Navigation Performance (RNP) First Edition - 1994

Related navigation documents

<u>EASA Acceptable means of Compliance</u>

AMC 25-11 Electronic Display Systems

AMC 20-5 Acceptable Means of Compliance for Airworthiness Approval and Operational Criteria for the use of the NAVSTAR Global Positioning System (GPS)

AMC 20-115 (latest edition) Software considerations for certification of airborne systems and equipment

FAA Advisory Circulars

AC 20-121 A	Airworthiness Approval of LORAN C for use in the U.S. National Airspace System
AC 20-130()	Airworthiness Approval of Multi-sensor Navigation Systems for use in the U.S. National Airspace System
AC 20-138	Airworthiness Approval of NAVSTAR Global Positioning System (GPS) for use as a VFR and IFR Supplemental Navigation System
AC 25-4	Inertial Navigation Systems (INS)
AC 25-15	Approval of FMS in Transport Category Airplanes
AC 90-45 A	Approval of Area Navigation Systems for use in the U S. National Airspace System

ETSOs

ETSO-C115b	Airborne Area Navigation Equipment Using Multi Sensor Inputs
ETSO-C129a	Airborne Supplemental Navigation Equipment Using the Global Positioning System (GPS)
ETSO-C145	Airborne Navigation Sensors Using the Global Positioning System (GPS) Augmented by the Wide Area Augmentation System (WAAS).
ETSO-C146	Stand-Alone Airborne Navigation Equipment Using the Global Positioning System (GPS) Augmented by the Wide Area Augmentation System (WAAS)

EUROCAE/RTCA documents

ED-27	Minimum Operational Performance Requirements (MOPR) for Airborne Area Navigation Systems, based on VOR and DME as sensors
ED-28	Minimum Performance Specification (MPS) for Airborne Area Navigation Computing Equipment based on VOR and DME as sensors
ED-39	MOPR for Airborne Area Navigation Systems, based on two DME as sensors
ED-40	MPS for Airborne Computing Equipment for Area Navigation System using two DME as sensors.
ED-58	Minimum Operational Performance Specification (MOPS) for Area Navigation Equipment using Multi-Sensor Inputs
ED-72()	MOPS for Airborne GPS Receiving Equipment
DO-180()	Minimum Operational Performance Standards (MOPS) for Airborne Area Navigation Equipment Using a Single Collocated VOR/DME Sensor Input
DO-187	MOPS for Airborne Area Navigation Equipment Using Multi Sensor Inputs
DO-200	Preparation, Verification and Distribution of User-Selectable Navigation Data Bases
DO-201	User Recommendations for Aeronautical Information Services
DO-208	MOPS for Airborne Supplemental Navigation Equipment Using Global Positioning System (GPS)

3 SYSTEMS CAPABILITY

Area navigation (RNAV) is a method which permits aircraft navigation along any desired flight path within the coverage of either station referenced navigation aids or within the limits of the capability of self-contained aids, or a combination of both methods.

In general terms, RNAV equipment operates by automatically determining aircraft position from one, or a combination, of the following together with the means to establish and follow a desired path:

VOR/DME

DME/DME

INS* or IRS

LORAN C*

GPS*

Equipment marked with an asterisk *, is subject to the limitations contained in paragraph 4.4.2.

4 AIRWORTHINESS APPROVAL

4.1 Criteria For Basic RNAV System

4.1.1 Accuracy

The navigation performance of aircraft approved for Basic RNAV operations within European airspace requires a track keeping accuracy equal to or better than +/- 5 NM for 95 % of the flight time. This value includes signal source error, airborne receiver error, display system error and flight technical error.

This navigation performance assumes the necessary coverage provided by satellite or ground based navigation aids is available for the intended route to be flown.

4.1.2 Availability and Integrity

Acceptable means of compliance for assessment of the effects associated with the loss of navigation function or erroneous display of related information is given in AMC 25-11 paragraph 4 a (3)(viii).

The minimum level of availability and integrity required for Basic RNAV systems for use in designated European airspace can be met by a single installed system comprising one or more sensors, RNAV computer, control display unit and navigation display(s) (e.g. ND, HSI or CDI) provided that the system is monitored by the flight crew and that in the event of a system failure the aircraft retains the capability to navigate relative to ground based navigation aids (e.g. VOR, DME and NDB).

4.2 Functional Criteria

4.2.1 Required Functions

The following system functions are the minimum required to conduct Basic RNAV operations.

(a) Continuous indication of aircraft position relative to track to be displayed to the pilot flying on a navigation display situated in his primary field of view

In addition where the minimum flight crew is two pilots, indication of aircraft position relative to track to be displayed to the pilot not flying on a navigation display situated in his primary field of view

(b) Display of distance and bearing to the active (To) waypoint

(c) Display of ground speed or time to the active (To) waypoint

(d) Storage of waypoints; minimum of 4

(e) Appropriate failure indication of the RNAV system, including the sensors.

4.2.2 Recommended Functions

In addition to the requirements of paragraph 4.2.1, the following system functions and equipment characteristics are recommended:

(a) Autopilot and/or Flight Director coupling

(b) Present position in terms of latitude and longitude

(c) 'Direct To' function

(d) Indication of navigation accuracy (e.g. quality factor)

(e) Automatic channel selection of radio navigation aids

(f) Navigation data base

(g) Automatic leg sequencing and associated turn anticipation

4.3 Aircraft Flight Manual - MMEL (Master Minimum Equipment List)

The basis for certification should be stated in the Aircraft Flight Manual (AFM), together with any RNAV system limitations. The AFM may also provide the appropriate RNAV system operating and abnormal procedures applicable to the equipment installed, including, where applicable, reference to required modes and systems configuration necessary to support an RNP capability.

The (Master) Minimum Equipment List MMEL/MEL should identify the minimum equipment necessary to satisfy the Basic RNAV criteria defined in paragraphs 4.1 and 4.2.

4.4. Basic RNAV Systems - Acceptable Means Of Compliance

4.4.1 Acceptable Means of Compliance

Navigation systems which are installed on aircraft in accordance with the advisory material contained within FAA AC 90-45A, AC 20-130(), AC 20-138 or AC 25-15, are acceptable for Basic RNAV operations. Where reference is made in the AFM to either the above advisory material or the specific levels of available navigation performance (RNP), no further compliance statements will be required.

Compliance may be based also on the lateral navigation standards defined in ETSO-C115b, ETSO-C129a, ED-27/28, ED-39/40, DO-187/ED-58 or DO-180(). However, qualification of the equipment to these standards, in itself, is not considered as sufficient for the airworthiness approval.

4.4.2 Limitations on the Use of Navigation Systems

The following navigation systems, although offering an RNAV capability, have limitations for their use in Basic RNAV operations.

4.4.2.1 INS

INS without a function for automatic radio updating of aircraft position and approved in accordance with AC 25-4, when complying with the functional criteria of paragraph 4.2.1, may be used only for a maximum of 2 hours from the last alignment/position update performed on the ground. Consideration may be given to specific INS configurations (e.g. triple mix) where either equipment or aircraft manufacturer's data, justifies extended use from the last on-ground position update.

INS with automatic radio updating of aircraft position, including those systems where manual selection of radio channels is performed in accordance with flight crew procedures, should be approved in accordance with AC 90-45A or equivalent material.

4.4.2.2 LORAN C

No EASA advisory material currently exists for operational or airworthiness approval of LORAN C system within European airspace. Where LORAN C coverage within European Airspace permits use on certain Basic RNAV routes, AC 20-121A may be adopted as a compliance basis.

4.4.2.3 GPS

The use of GPS to perform Basic RNAV operations is limited to equipment approved to ETSO-C129a, ETSO-C 145, or ETSO-C 146 and which include the minimum system functions specified in paragraph 4.2.1. Integrity should be provided by Receiver Autonomous Integrity Monitoring (RAIM) or an equivalent means within a multi-sensor navigation system. The equipment should be approved in accordance with the AMC 20-5. In addition, GPS stand-alone equipment should include the following functions:

(a) Pseudorange step detection

(b) Health word checking.

These two additional functions are required to be implemented in accordance with ETSO-C129a criteria.

Traditional navigation equipment (e.g. VOR, DME and ADF) will need to be installed and be serviceable, so as to provide an alternative means of navigation.

Note: Where GPS stand-alone equipment provides the only RNAV capability installed onboard the aircraft, this equipment, on its own, may be incompatible with a future airspace infrastructure such as Precision RNAV routes, terminal procedures, and where implementation of an augmented satellite navigation system will allow, the decommissioning of traditional ground based radio navigation aids.

5 OPERATIONAL CRITERIA FOR USE OF GPS STAND-ALONE EQUIPMENT

5.1 General Criteria

GPS stand-alone equipment approved in accordance with the guidance provided in this Leaflet, may be used for the purposes of conducting Basic RNAV operations, subject to the operational limitations contained herein. Such equipment should be operated in accordance with procedures acceptable to the Authority. The flight crew should receive appropriate training for use of the GPS stand-alone equipment for the normal and abnormal operating procedures detailed in paragraphs 5.2 and 5.3.

5.2 Normal Procedures

The procedures for the use of navigational equipment on Basic RNAV routes should include the following:

(a) During the pre-flight planning phase, given a GPS constellation of 23 satellites or less (22 or less for GPS stand-alone equipment that incorporate pressure altitude aiding), the availability of GPS integrity (RAIM) should be confirmed for the intended flight (route and time). This should be obtained from a prediction program either ground-based, or provided as an equipment function (see Annex 1), or from an alternative method that is acceptable to the Authority.

Dispatch should not be made in the event of predicted continuous loss of RAIM of more than 5 minutes for any part of the intended flight.

(b) Where a navigation data base is installed, the data base validity (current AIRAC cycle) should be checked before the flight;

(c) Traditional navigation equipment (e.g. VOR, DME and ADF) should be selected to available aids so as to allow immediate cross-checking or reversion in the event of loss of GPS navigation capability.

5.3 Abnormal Procedures in the event of loss of GPS navigation capability

The operating procedures should identify the flight crew actions required in the event of the GPS stand-alone equipment indicating a loss of the integrity monitoring detection (RAIM) function or exceedance of integrity alarm limit (erroneous position). The operating procedures should include the following:

(a) In the event of loss of the RAIM detection function, the GPS stand-alone equipment may continue to be used for navigation. The flight crew should attempt to cross-check the aircraft position, where possible with VOR, DME and NDB information, to confirm an acceptable level of navigation performance. Otherwise, the flight crew should revert to an alternative means of navigation.

(b) In the event of exceedance of the alarm limit, the flight crew should revert to an alternative means of navigation.

ANNEX 1

GPS Integrity Monitoring (RAIM) Prediction Program

Where a GPS Receiver Autonomous Integrity Monitoring (RAIM) Prediction Program is used as a means of compliance with paragraph 5.2(a) of this document, it should meet the following criteria:

1. The program should provide prediction of availability of the integrity monitoring (RAIM) function of the GPS equipment, suitable for conducting Basic RNAV operations in designated European airspace.

2. The prediction program software should be developed in accordance with at least level D guidelines as defined in the industry documents referred in the latest edition of AMC 20-115.

3. The program should use either a RAIM algorithm identical to that used in the airborne equipment, or an algorithm based on assumptions for RAIM prediction that give a more conservative result.

4. The program should calculate RAIM availability based on a satellite mask angle of not less than 5 degrees, except where use of a lower mask angle has been demonstrated to be acceptable to the Authority.

5. The program should have the capability to manually designate GPS satellites which have been notified as being out of service for the intended flight.

6. The program should allow the user to select:

a) the intended route and declared alternates;

b) the time and duration of the intended flight.

AMC 20-27A Airworthiness Approval and Operational Criteria for RNP APPROACH (RNP APCH) Operations Including APV BARO-VNAV Operations

1. PURPOSE

This AMC provides an acceptable means that can be used to obtain airworthiness approval of an Area Navigation (RNAV) system based on a Global Navigation Satellite System (GNSS) stand-alone receiver or multi-sensor system including at least one GNSS sensor in order to conduct RNP Approach (RNP APCH) operations.

RNP APCH procedures are characterised by existing charted RNAV (GNSS) approach procedures designed with straight final approach segments.

This AMC also defines operational criteria necessary to conduct safely RNP APCH operations in designated European airspace.

This AMC addresses RNP APCH operation without vertical guidance (Non Precision Approach operation) and with vertical guidance based on barometric vertical navigation (APV BARO-VNAV operation). Final approaches utilising SBAS (Localiser Performance with Vertical guidance (LPV) operation) are addressed in separate AMC material.

APV BARO-VNAV systems are based on barometric altimetry for the determination of the aircraft position in the vertical axis. The final approach segment of VNAV instrument flight procedures are performed using vertical guidance to a vertical path computed by the on-board RNAV system. The vertical path is contained in the specification of the instrument procedure within the RNAV system navigation database. For other phases of flight, barometric VNAV provides vertical path information that can be defined by altitudes at fixes in the procedure. It should be noted that there is no vertical requirement in this AMC associated to the use of VNAV guidance outside of the final approach segment. Vertical navigation on the initial or intermediate segment can be conducted without VNAV guidance.

An applicant may elect to use an alternative means of compliance. However, those alternative means of compliance must meet safety objectives that are acceptable to the Agency or the competent authority. Compliance with this AMC is not mandatory. Use of the terms *shall* and *must* apply only to an applicant who elects to comply with this AMC in order to obtain airworthiness approval or to demonstrate compliance with the operational criteria.

2. BACKGROUND

This document addresses and defines airworthiness and operational criteria related to RNAV systems approved for RNP APCH based on GNSS with or without vertical guidance based on BARO-VNAV. It relates to the implementation of area navigation within the context of the Single European Sky[1], in particular in relation to the verification of conformity of the airborne constituents, per Article 5 of EC Regulation 552/2004[2]. It addresses general certification considerations of stand-alone and multi-sensor systems on-board aircraft, including their functional requirements, accuracy, integrity, continuity of function, and limitations, together with operational considerations.

---

[1] Regulation (EC) No 549/2004 of the European Parliament and of the Council of 10 March 2004 laying down the framework for the creation of the single European sky (the framework Regulation) (O J L 096 , 31/03/2004, p. 01).

[2] Regulation (EC) No 552/2004 of the European Parliament and of the Council of 10 March 2004 on the interoperability of the European Air Traffic Management network (O J L 096, 31.3.2004, p. 26).

This document is applicable to RNP APCH operations only. It does not address RNP AR APCH operations (see AMC 20-26).

This AMC identifies the airworthiness and operational requirements for RNP APCH operations including APV BARO-VNAV operation. Operational compliance with these requirements must be addressed through national operational regulations, and may require a specific operational approval in some cases.

Use of BARO-VNAV information for RNP APCH with LNAV minima only is possible using the CDFA (Continuous Descent Final Approach) concept. This use is possible provided the navigation system is able to compute a vertical continuous descent path on the Final Approach segment and operator complies with EU OPS 1.430 section. It should be noted that this AMC does not address such operational approval authorisation.

3. SCOPE

This AMC includes airworthiness and operational criteria related to RNAV systems based on a GNSS stand-alone receiver, or multi-sensor systems including at least one GNSS sensor, intended to be used under Instrument Flight Rules, including Instrument Meteorological Conditions, in designated European airspace. It contains also airworthiness and operational criteria related to systems based upon the use of barometric altitude and RNAV information in the definition of vertical paths and vertical tracking to a path to conduct APV BARO-VNAV operation.

Section 4.2 of this AMC refers to documents which contribute to the understanding of the RNP APCH concept and which may support an application for approval. However, it is important that an operator evaluates his aircraft system and the proposed operational procedures against the criteria of this AMC.

Compliance with this AMC does not, by itself, constitute an operational authorisation to conduct RNP APCH operations. Aircraft operators should apply to their national authority. Since this AMC has been harmonised with other RNP implementation and operational criteria outside of Europe, i.e. USA/FAA, it is expected to facilitate interoperability and ease the effort in obtaining operational authorisation by operators.

This AMC does not cover RNP approaches where special authorisation is required (RNP AR APCH). RNP AR APCH is addressed in a separate AMC.

4. REFERENCE DOCUMENTS

4.1 Related Requirements

- CS 25.1301, 25.1302, 25.1307, 25.1309, 25.1316, 25.1321, 25.1322, 25.1325, 25.1329, 25.1431, 25.1581.
- CS 23.1301, 23.1309, 23.1311, 23.1321, 23.1322, 23.1325, 23.1329, 23.1335, 23.1431, 23.1581.
- Equivalent requirements of CS/FAR 27 and 29 if applicable.
- EU-OPS[3] 1.035, 1.220, 225, 1.243, 1.290, 1.295, 1.297, 1.400, 1.420, 1.845, 1.865, 1.870, 1.873 and 1.975.
- JAR-OPS 3.243, 3.845, 3.865.
- National operational regulations.

[3] Council Regulation (EEC) No 3922/91 on the harmonisation of technical requirements and administrative procedures in the field of civil aviation. Regulation as last amended by Regulation (EC) No 1899/2006 of the European Parliament and of the Council of 12 December 2006 (O L J 377, 27.12.2006, p. 1).

4.2 Related Material

4.2.1 ICAO

ICAO Annex 10	International Standards and Recommended Practices- Aeronautical Telecommunications
ICAO Doc 7030/4	Regional Supplementary Procedures
ICAO Doc 9613	Performance Based Navigation Manual (PBN)
ICAO Doc 8168	PANS OPS (Procedures for Air Navigation Services-Aircraft Operations)

4.2.2 EASA

AMC 25-11	Electronic Flight Deck Display
AMC 20-5	Airworthiness Approval and Operational Criteria for the use of the Navstar Global Positioning System (GPS)
AMC 20-115 (latest edition)	Software considerations for certification of airborne systems and equipment
ETSO-C115( )	Airborne Area Navigation Equipment using Multi-Sensor Inputs
ETSO-C129( )	Airborne Supplemental Navigation Equipment Using the Global Positioning System (GPS)
ETSO-C145( )	Airborne Navigation Sensors Using the Global Positioning System (GPS) Augmented by the Wide Area Augmentation System (WAAS)
ETSO-C146( )	Stand-Alone Airborne Navigation Equipment Using the Global Positioning System (GPS) Augmented by the Wide Area Augmentation System (WAAS)
ETSO-C106( )	Air Data Computer
EASA OPINION Nr. 01/2005	Conditions for Issuance of Letters of Acceptance for Navigation Database Suppliers by the Agency (i.e. an EASA Type 2 LoA). EASA OPINION Nr. 01/2005 on 'The Acceptance of Navigation Database Suppliers' dated 14 Jan 05

4.2.3 FAA

AC 25-4	Inertial Navigation Systems (INS)
AC 25-11( )	Electronic Display Systems
AC 20-129	Airworthiness Approval of Vertical Navigation (VNAV) Systems or use in the U.S. National Airspace System (NAS) and Alaska
AC 20-138( )	Airworthiness Approval of GNSS equipment
AC 20-130A	Airworthiness approval of navigation or flight management systems integrating multiple navigation sensors
AC 23-1309-1C	Equipment, systems, and installation in Part-23 airplanes
AC 20-153	Acceptance of data processes and associated navigation data bases

4.2.4 Technical Standard Orders

FAA TSO-C115( )	Airborne Area Navigation Equipment using Multi-Sensor Inputs
FAA TSO-C129( )	Airborne Supplemental Navigation Equipment Using the Global Positioning System (GPS)
FAA TSO-C145( )	Airborne Navigation Sensors Using the Global Positioning System (GPS) Augmented by the Wide Area Augmentation System (WAAS)
FAA TSO-C146( )	Stand-Alone Airborne Navigation Equipment Using the Global Positioning System (GPS) Augmented by the Wide Area Augmentation System (WAAS)
FAA TSO-C106( )	Air Data Computer

4.2.5 EUROCAE/RTCA, SAE and ARINC

ED 26	MPS for airborne Altitude measurements and coding systems
ED 72A	Minimum Operational Performance Specification for Airborne GPS Receiving Equipment
ED-75( )/DO-236( )	Minimum Aviation System Performance Standards: Required Navigation Performance for Area Navigation
ED-76/DO-200A	Standards for Processing Aeronautical Data
ED-77/DO-201A	Standards for Aeronautical Information
DO 88	Altimetry
DO 187	Minimum operational performances standards for airborne area navigation equipments using multi-sensor inputs
DO 208	Minimum Operational Performance Standards for Airborne Supplemental Navigation Equipment Using Global Positioning System (GPS)
DO-229( )	Minimum Operational Performance Standards for Global Positioning System/Wide Area Augmentation System Airborne equipment
ARINC 424	Navigation System Data Base
ARINC 706	Mark 5 Air Data System

5. ASSUMPTIONS

Applicants should note that this AMC is based on the following assumptions:

5.1 Navaid infrastructure

GNSS is the primary navigation system to support RNP APCH procedures.

The acceptability of the risk of loss of RNP APCH capability for multiple aircraft due to satellite failure, loss of the on board monitoring, alerting function (e.g. RAIM holes) and radio frequency interference, will be considered by the responsible airspace authority.

5.2 Obstacle clearance

5.2.1 RNP APCH without BARO-VNAV guidance

Detailed guidance on obstacle clearance is provided in PANS-OPS (Doc 8168, Volume II). Missed approach procedure may be supported by either RNAV or conventional (e.g. based on NDB, VOR, DME) segments.

Procedures design will take account of the absence of a VNAV capability on the aircraft.

5.2.2 APV BARO-VNAV

BARO-VNAV is applied where vertical guidance and information is provided to the flight crew on instrument approach procedures containing a vertical path defined by a vertical path angle.

Detailed guidance on obstacle clearance is provided in PANS-OPS (Doc 8168, Volume II). Missed approach procedure may be supported by either RNAV or conventional (e.g. based on NDB, VOR, DME) segments.

5.3 Publication

The instrument approach chart will clearly identify the RNP APCH application as $RNAV_{(GNSS)}$.

For non APV BARO-VNAV operation, the procedure design will rely on normal descent profiles and the chart will identify minimum altitude requirements for each segment, including an LNAV OCA(H).

For APV BARO-VNAV operation, charting will follow the standards of ICAO Annex 4 to the Convention on International Civil Aviation for the designation of an RNAV procedure where the vertical path is specified by a glide path angle. The charting designation will remain consistent with the current convention and will promulgate a LNAV/VNAV OCA(H).

If the missed approach segment is based on conventional means, the navaid facilities or airborne navigation means that are necessary to conduct the missed approach will be identified in the relevant publications (e.g. approach charts).

The navigation data published in the applicable AIP for the procedures and supporting navigation aids will meet the requirements of ICAO Annex 15 and Annex 4 to the Convention on International Civil Aviation. The chart will provide sufficient data to support navigation data base checking by the crew (including waypoint name, track, distance for each segment and vertical path angle).

All procedures will be based upon WGS 84 coordinates.

5.4 Communication, ATS surveillance and ATC coordination

RNP APCH does not include specific requirements for communication or ATS surveillance. Adequate obstacle clearance is achieved through aircraft performance, operating procedures and procedure design. Where reliance is placed on the use of radar to assist contingency procedures, its performance will be shown to be adequate for that purpose, and the requirement for a radar service will be identified in the AIP.

RT phraseology appropriate to RNP APCH operations will be promulgated.

It is expected that ATC will be familiar with aircraft VNAV capability, as well as issues associated with altimeter setting and temperature effect potentially affecting the integrity of the APV BARO-VNAV operation.

The particular hazards of a terminal and approach area and the impact of contingency procedures following multiple loss of RNP APCH capability will be assessed.

ATC may use radar vectoring techniques to place aircraft onto final approach axis when the RNAV system supports this function. Air Navigation Service Providers implementing such operation in their airspace should inform airspace users of this operational possibility in the relevant AIP.

5.5 Service provider assumption for APV BARO-VNAV operation.

It is expected that air navigation service provision will include data and information to enable correct and accurate altimeter setting on-board the aircraft, as well as local temperature. This data will be from measurement equipment at the airport where the approach is to take place (remote or regional pressure setting are not authorised).

The specific medium for transmission of this data and information to the aircraft may include voice communication, ATIS or other media. In support of this, it is also expected that MET service providers will assure the accuracy, currency and availability of meteorological data supporting APV BARO-VNAV operations. In order to minimise the potential for miss-setting of barometric reference, Air Traffic Controllers will confirm QNH with flight crews prior to commencement of the approach.

6. RNP APCH AIRWORTHINESS CRITERIA

6.1 General

The following airworthiness criteria are applicable to the installation of RNAV system intended for IFR approach operation, certified according to CS-23, -25, -27 and -29

This AMC uses FAA Advisory Circulars AC 20-138/AC 20-138A (GPS stand-alone system) or AC 20-130A (Multi-sensors systems) as the basis for the airworthiness approval of an RNAV system based on GNSS. For APV BARO-VNAV operation, this AMC uses FAA Advisory Circular AC 20-129 as the airworthiness basis with additional requirements.

This AMC is to be used as Interpretative Material to show compliance with the applicable CS codes on each application, e.g. xx.1301 and xx.1309.

6.2 Equipment qualification

6.2.1 General

If the RNAV installation is based on GNSS stand-alone system, the equipment shall be approved in accordance with TSO-C129a/ETSO-C129a Class A1 or ETSO-C146()/TSO-C146() Class Gamma, operational class 1, 2 or 3.

If the RNAV installation is based on GNSS sensor equipment used in a multi-sensor system (e.g. FMS), the GNSS sensor shall be approved in accordance with TSO-C129( )/ ETSO-C129( ) Class B1, C1, B3, C3 or ETSO-C145( )/TSO-C145( ) class Beta, operational class 1, 2 or 3.

Multi-sensor systems using GNSS should be approved in accordance with AC20-130A or ETSO-C115b/TSO-C115b, as well as having been demonstrated for RNP capability.

Note 1: For GNSS receiver approved in accordance with ETSO-C129()/TSO-C129(), capability for satellite Fault detection and Exclusion (FDE) is recommended, to improve Continuity of function.

Note 2: GNSS receivers approved in accordance with ETSO-145/TSO-C145a or ETSO-C146/TSO-C146a (DO 229C) and used outside SBAS coverage area may trigger inappropriate Loss of Integrity (LOI) warning. DO229D paragraph 2.1.1.6 provides a correct satellite selection scheme requirement to address this issue. Although most of the ETSO-C145/TSO-C145a or ETSO-146/TSO-C146a approved receivers comply with this satellite selection scheme, a confirmatory statement from the equipment manufacturer is still necessary. It should be noted that such confirmatory statement is not necessary for equipment compliant with TSO-C145b or TSO-C146b.

6.2.2 Altimeter sensor requirement for APV BARO-VNAV operation

In addition to requirements of paragraph 6.2.1 above, the RNAV equipment that automatically determines aircraft position in the vertical plane should use inputs from equipment that can include:

a) ETSO-C106/TSO-C106, Air Data Computer; or
b) Air data system, ARINC 706, Mark 5 Air Data System, ARINC 738 (Air Data and Inertial Reference System); or
c) Barometric altimeter system compliant with DO-88 'Altimetry' and/or ED-26 'MPS for Airborne Altitude Measurements and Coding Systems'; or

d) Type certified integrated systems providing an Air Data System capability comparable to item b).

6.3 Accuracy

6.3.1 Horizontal

The Lateral and Longitudinal Total System Error (TSE) of the on-board navigation system must be equal to or better than:

a) ±1 NM for 95 % of the flight time for the initial and intermediate approach segments and for the RNAV missed approach.

Note: There is no specific RNAV accuracy requirement for the missed approach if this segment is based on conventional means (VOR, DME, NDB) or on dead reckoning.

b) ±0.3 NM for 95 % of the flight time for the final approach segment.

The Lateral Total System Error (TSE) is dependent on the Navigation System Error (NSE), Path Definition Error (PDE) and Flight Technical Error (FTE).

In order to satisfy the ±0.3 NM TSE accuracy for the final approach segment, FTE (95 %) should not exceed ±0.25 NM whatever the operating mode (manual, flight director or Autopilot):

a) A demonstrated FTE (95 %) of ±0.25NM is assumed for manual mode if a standardised CDI is installed (compliant with the full-scale deflection sensitivity requirement of TSO-C129a paragraph (a).3.(viii) or RTCA/DO-229() paragraph 2.2.1.4.2.1) Otherwise, it should be demonstrated that an FTE of ±0.25 NM can be maintained under all foreseeable conditions through a dedicated flight test evaluation.

b) A demonstrated FTE (95 %) of ±0.25NM is assumed when coupled to a flight director.

c) A demonstrated FTE (95 %) of ±0.125 NM is assumed when coupled to an autopilot.

Outside of the Final Approach Segment, a demonstrated FTE of ±0.5 NM may be assumed.

Positioning data from other types of navigation sensors may be integrated with the GNSS data provided it does not cause position errors to exceed the Total System Error (TSE) budget, otherwise a means must be provided to deselect the other navigation sensor types.

Note: The horizontal positioning error component of TSE is assumed to be equal to the 2D navigation accuracy of systems/sensors qualified to AC20-138, 20-138A, and 20-130A

An acceptable means of complying with these accuracy requirements is to have an RNAV system approved for RNAV approaches in accordance with 2D navigation accuracy criteria of FAA AC 20-138, AC 20-138A or AC 20-130A.

6.3.2 Vertical accuracy for APV BARO-VNAV operation.

a) Altimetry System Error (ASE)

Altimetry system performance is demonstrated separately from the APV BARO-VNAV certification through the static pressure system certification process. With such approval (e.g. CS 25.1325), each system must be designed and installed so that the error in indicated pressure altitude, at sea-level, with a standard atmosphere, excluding instrument calibration error, does not result in an error of more than ±9 m (±30 ft) per 185 km/hr (100 knots) speed for the appropriate configuration in the speed range between 1·23 VSR0 with wing-flaps extended and 1·7 VSR1 with wing-flaps retracted. However, the error need not be less than ±9 m (±30 ft).

Altimetry systems meeting such a requirement will satisfy the Altimetry System Error (ASE) requirements for APV BARO-VNAV operation. No further demonstration or compliance is necessary.

Note 1: Altimetry Error refers to the electrical output and includes all errors attributable to the aircraft altimetry installation including position effects resulting from normal aircraft flight attitudes. In high performance aircraft, it is expected that altimetry correction will be provided. Such correction should be done automatically. In lower performance aircraft, upgrading of the altimetry system may be necessary.

Note 2: Positioning data from other sources may be integrated with the barometric altitude information provided it does not cause position errors exceeding the vertical accuracy requirement.

b) VNAV Equipment Error

The error of the airborne VNAV equipment (excluding altimetry, horizontal coupling and flight technical error) on a 99.7 per cent probability basis should be demonstrated to be less than:

	Descent Along Specified Vertical Profile (angle) (ft)
At or below 5000 ft (MSL)	100
5000 ft to 10000 ft (MSL)	150
10000 ft to 15000 ft (MSL)	220

Note 1: VNAV Equipment Error is the error associated to the vertical path computation. It includes path definition error (PDE) and approximation made by the VNAV equipment for the vertical path construction if any.

c) Horizontal Coupling Error

The Horizontal coupling error (vertical error component of along track positioning error) is a function of the horizontal NSE (see 6.3.1) and is directly reflected in the along track tolerance offset used in APV BARO-VNAV procedure design criteria.

This Horizontal Coupling error in this context is assumed to be 24 ft on a 99.7 per cent probability basis using a longitudinal positioning accuracy of 0.05 NM at 95 % and a vertical path of 3°.

Note: For straight approaches, it is assumed that longitudinal accuracy does not include an FTE component. An arbitrary TSE (based on NSE) of 0.2NM is applied instead of 0.3NM.

d) Vertical Flight Technical Error (FTE)

The vertical FTE on a 99.7 per cent probability basis should be demonstrated to be less than

	Descent Along Specified Vertical Profile (angle) (ft)
At or below 5000 ft (MSL)	150
5000 ft to 10000 ft (MSL)	150
10000 ft to 15000 ft (MSL)	150

Note 1: FTE performance requirements are more stringent compared with AC 20-129 and the ICAO PBN manual where 200 ft (at or below 5000 ft MSL) and 300 ft (from 5000 ft to 15000 ft MSL) are required.

Note 2: Use of a flight director or autopilot may be required to support such an FTE requirement.

e) Vertical Total System Error (TSE)

The Vertical Total System Error (using the Root Sum Square (RSS) of all errors components described above) on a 99.7 per cent probability basis is as follow:

	Altimeter System Error[4]	VNAV Equipment Error	Horizontal coupling Error	Flight Technical Error	**Vertical Total System Error**
At or below 5000 ft (MSL)	80 ft	100 ft	24 ft	150 ft	**199 ft**
5000 ft to 10000 ft MSL)	106 ft	150 ft	24 ft	150 ft	**238 ft**
10000 ft to 15000 ft MSL)	127 ft	220 ft	24 ft	150 ft	**296 ft**

Note 1: If an installation results in larger Fight Technical Errors, the Total Vertical Error for the system should be determined by combining the demonstrated errors using the root sum square (RSS) method. The result should be less than the values listed.

Note 2: The manual monitoring of the altimeters to comply with the DA/DH is independent of the BARO-VNAV system and provides additional mitigation.

An acceptable means of complying with the above accuracy requirements is to have the VNAV system approved for RNAV approaches in accordance with FAA AC 20-129 and to provide evidence that the FTE, or VTSE, or operation procedures to bound the FTE are within the required limits.

f) Vertical Path Error at FAP due to the vertical fly-by transition

Error due to the capture of the vertical path starting from the FAP altitude should be limited. This momentary deviation below the published minimum procedure altitude at the FAP is acceptable provided the deviation is limited to no more than 50 feet (assuming no VNAV equipment error).

Note: ED-75 B paragraphs 1.5.7.2 and 3.2.8.5 provides guidance regarding the VNAV path transitions and, in particular, the vertical fly-by transition

6.4 Integrity

During operations on instrument approach procedures, the probability of displaying misleading navigational or positional information to the flight crew during the approach, including the final segment, shall be remote.

In the horizontal plane and during operations on the initial, intermediate segment and for the RNAV missed approach of an RNP APCH, the system, or the system and pilot in combination, shall provide an alert if the accuracy requirement is not met, or if the probability that the lateral TSE exceeds 2 NM is greater than 10^{-5}. During operations on the final approach segment of an RNP APCH, the system, or the system and pilot in

---

[4] The ASE value has been computed using the following formula:

$$ASE\ (ft) = -8.8\ 10^{-8} \times (h+\Delta h)^2 + 6.5\ 10^{-3} \times (h+\Delta h) + 50$$

where h is the height of the local altimetry reporting station and Δh is the height of the aircraft above the reporting station.

combination, shall provide an alert if the accuracy requirement is not met, or if the probability that the lateral TSE exceeds 0.6 NM is greater than 10^{-5}.

For APV BARO-VNAV operation, in the vertical plane the integrity is relying on system development assurance, crew procedures and use of airborne systems independent from the VNAV computer system (e.g. primary altimeter system). The integrity requirement is satisfied by applying appropriate quantitative numerical methods, qualitative operational and procedural considerations and mitigations. The airborne VNAV system must be designed in accordance with the major failure condition regarding the computation of an erroneous vertical guidance. Two independent altimetry systems (sources and displays) must be operational and crew must cross-check the displayed altitude during the approach and, in particular, when determining the Decision Altitude (DA). Operator procedures and crew training should highlight the importance of having the current altimeter setting for the selected instrument procedure and runway and the respect of temperature limitation if the VNAV system does not compensate automatically.

Note 1 An airborne safety objective of Remote recognises that not only is the navigation system design evaluated consistent with known industry and regulatory system safety assessment views, but is now augmented with a comprehensive assessment of system performance assurance, system features/functions, human interface, flight crew procedures, maintenance and training, that is unique for RNP. The result is that the safety assurance provided greatly exceeds that of conventional navigation systems.

Note 2: An airborne objective of Remote is applicable to an instrument approach in particular on the final segment, i.e. from the FAF down to the runway. It is possible to satisfy this objective when considering the RNP system's unique requirements for RNP monitoring and integrity alerting, situational awareness information, error checking via the human machine interface and cockpit displays of independent flight information. Furthermore, the pilot should respect all vertical constraints associated to the procedure (start of descent, step-down fix,…) in order to respect obstacle clearance.

Note 3: The probability to fail to detect a GPS-induced position error larger than 0.3 NM is less than 10^{-7}/Fh if the receiver is compliant with ETSO-C129( )/TSO-C129( ), ETSO-C145/TSO-C145a or ETSO-C146/TSO-C146a. This 10^{-7}/Fh criterion is the combined probability of the missed detection probability (less than or equal to 10^{-3}/Fh) and the probability of receiving an erroneous satellite signal (less than or equal to10^{-4}/Fh).

Note 4: Traditionally, this requirement has not specifically addressed the airborne system operational software or airborne system databases (e.g. navigation database). However, it is expected that where the RNAV airborne software has been previously shown compliant with the criteria of, as a minimum Level C in the industry documents referred to in the latest edition of AMC 20-115, it is acceptable for the operations associated with this AMC.

Note 5: Probability terms are defined in CS AMC 25.1309, AC 23.1309-1() AC 27-1B or AC 29-2C.

Note 6: For RNP APCH operation, the on-board monitoring and alerting function is provided through the use of ABAS (RAIM or an equivalent algorithm) in conjunction with crew monitoring of the FTE.

Note 7: For aircraft and systems approved for RNP AR operations, per AMC 20-26, the crew alerting based upon RNP is an acceptable alternative.

6.5 Continuity of function

It shall be demonstrated that:

(a) The probability of loss of all navigation information is Remote.

(b) The probability of non-restorable loss of all navigation and communication functions is Extremely Improbable.

Loss of the RNP APCH functions with or without BARO-VNAV guidance is considered a minor failure condition if the operator can revert to a different navigation system and proceed to a suitable airport. For RNP APCH operations at least one RNAV system is required.

Note 1 From an operational point of view, the operator should develop contingency procedure for the loss of the RNP APCH capability during the approach.

Note 2: Probability terms are defined in CS AMC 25.1309, AC 23.1309-1() AC 27-1B or AC 29-2C.

7. FUNCTIONAL CRITERIA

7.1 Required Function for RNP APCH

Item	Functional Description
1	Navigation data, including a to/from indication and a failure indicator, must be displayed on a lateral deviation display (CDI, (E)HSI) and/or a navigation map display. These must be used as primary flight instruments for the navigation of the aircraft, for manoeuvre anticipation and for failure/status/integrity indication. They must meet the following requirements: 1) The displays must be visible to the pilot and located in the primary field of view (±15 degrees from pilot's normal line of sight) when looking forward along the flight path. 2) The lateral deviation display scaling must agree with any alerting and annunciation limits, if implemented. 3) The lateral deviation display must also have a full-scale deflection suitable for the current phase of flight and must be based on the required total system accuracy. For installations having a lateral deviation display, its full-scale deflection must be suitable for the phase of flight and based on the required track-keeping accuracy. Scaling is ±1NM for the initial and intermediate segments and ±0.3 NM for the final segment. 4) The display scaling may be set automatically by default logic or set to a value obtained from a navigation database. The full-scale deflection value must be known or made available for display to the flight crew. Enhanced navigation display (e.g. electronic map display or enhanced EHSI) to improve lateral situational awareness, navigation monitoring and approach (flight plan) verification could become mandatory if the RNAV installation does not support the display of information necessary for the accomplishment of these crew tasks.
2	Capability to continuously display, to the pilot flying, the RNAV computed desired path (DTK), and the aircraft position relative to the path (XTK), on the primary flight instruments for navigation of the aircraft. Note: Where the minimum flight crew is two pilots, it shall be possible for the pilot not flying to verify the desired path and the aircraft position relative to the path.
3	A navigation database, containing current navigation data officially promulgated for civil aviation; a) which can be updated in accordance with the AIRAC cycle and b) from which approach procedures can be retrieved in their entirety and loaded into the RNAV system. The resolution to which the data is stored must be sufficient to ensure that the

Item	Functional Description
	assumption of no path definition error is satisfied. The database shall be protected against flight crew modification of the stored data. Note: When a procedure is loaded from the database, the RNAV system is required to fly it as published. This does not preclude the flight crew from having the means to modify a procedure or route already loaded into the RNAV/GNSS system as permitted by paragraph 10. However, the procedure stored in the database must not be modified and must remain intact within the database for future use and reference.
4	Means to display the validity period of the navigation database to the flight crew.
5	Means to retrieve and display data stored in the navigation database relating to individual waypoints and navigation aids, to enable the flight crew to verify the procedure to be flown.
6	Capacity to load from the database into the RNAV system the whole approach procedure to be flown.
7	Display of the identification of the active (To) waypoint, either in the pilot's primary field of view, or on a readily accessible page on the RNAV CDU, readily visible to the flight crew.
8	Display of distance and bearing to the active (To) waypoint in the pilot's primary field of view. Where impracticable, the data may be displayed on a readily accessible page on the RNAV CDU, readily visible to the flight crew.
9	Display of distance between flight plan waypoints. The navigation system must provide the ability to display the distance between flight plan waypoints.
10	Display of distance from present position to any selected waypoint. The navigation system must provide the ability to display the distance to any waypoint selected by the flight crew. Such selection should not impact the active flight plan.
11	Display of ground speed or time to the active (To) waypoint, either in the pilot's primary field of view, or on a readily accessible page on the RNAV CDU, readily visible to the flight crew.
12	Capability for the 'Direct to' function.
13	Capability for automatic leg sequencing with display of sequencing to the flight crew.
14	Capability to execute database procedures including: a) fly-over and b) fly-by turns.
15	Capability to execute leg transitions and maintain tracks consistent with the following ARINC 424 path terminators (automatic capability), or their equivalent: Initial Fix (IF), Track to Fix (TF), Direct to Fix (DF) Note: Path terminators are defined in ARINC Specification 424, and their application is described in more detail in documents PANS-OPS, EUROCAE ED-75()/RTCA DO-236(), ED-77/RTCA DO-201A, and EUROCONTROL Document NAV.ET1.ST10.

Item	Functional Description
16	Capability to automatically execute leg transitions consistent with ARINC 424 FA path terminators, or the RNAV system must permit the pilot to fly a course and turn at a designated altitude. If manual intervention is necessary to turn at the designated altitude, the associated crew workload shall be assessed
17	Indication of the RNAV system failure leading to the loss of navigation function in the pilot's primary field of view (e.g. by means of a navigation warning flag on the navigation display).
18	Indication of the Loss Of Integrity (LOI) function (e.g. loss of RAIM) in the pilot's normal field of view (e.g. by means of an appropriately located annunciator). Note: Systems providing RNP alerts that reflect loss of GNSS integrity are considered acceptable.
19	Capability for the accomplishment of holding patterns and procedure turns. Activation of this function shall at least: a) Change automatic waypoint sequencing to manual. b) Permit the pilot to readily designate a waypoint and select a desired course (by means of a numerical keypad entry, HSI course pointer, CDI omni-bearing selector, etc.) to or from the designated waypoint (TO/FROM mode operation is acceptable). c) Retain all subsequent waypoints in the active flight plan in the same sequence. d) Permit the pilot to readily return to automatic waypoint sequencing at any time prior to the designated fix ('TO' waypoint) and continue with the existing flight plan.

7.2 Additional required function for APV BARO-VNAV operation

In addition to the required function specified in paragraph 7.1, the system shall meet the following requirements:

Item	Functional Description
1	APV BARO-VNAV deviation must be displayed on a vertical deviation display (HSI, EHSI, VDI). This display must be used as primary flight instruments for the approach. The display must be visible to the pilot and located in the primary field of view (±15 degrees from pilot's normal line of sight) when looking forward along the flight path. The deviation display shall have a suitable full-scale deflection based on the required vertical track error. The non-numeric display must allow the fight crew to readily distinguish if the vertical deviation exceeds ±75 feet. If the non-numeric display does not permit the fight crew to readily distinguish excessive vertical deviations, the approach must be conducted with the flight director and/or the autopilot and a numeric display should allow the pilot to readily distinguish if the vertical deviation exceeds ±75 feet

<table>
<tr><th>Item</th><th>Functional Description</th></tr>
<tr><td>2</td><td>Capability to continuously display, to the pilot flying, the vertical deviation relative to the Final approach segment on the primary flight instruments for navigation of the aircraft.

Note: Where the minimum flight crew is two pilots, a means for the pilot not flying to verify the desired path and the aircraft position relative to the path shall be provided.</td></tr>
<tr><td>3</td><td>The navigation system must be capable of defining a vertical path in accordance with the published vertical path.

Note: The VNAV equipment error budget (see 6.3.2.b) includes the path approximation error.</td></tr>
<tr><td>4</td><td>User Interface (Displays and Control)
The display readout and entry resolution for vertical navigation information shall be as follow:

<table>
<tr><th colspan="2">Parameter</th><th>Display resolution</th><th>Entry resolution</th></tr>
<tr><td rowspan="2">Altitude</td><td>Above altitude transition level</td><td>Flight Level</td><td>Flight Level</td></tr>
<tr><td>Below altitude transition level</td><td>1 foot</td><td>1 foot</td></tr>
<tr><td colspan="2">Vertical Path Deviation</td><td>10 feet</td><td>Not applicable</td></tr>
<tr><td colspan="2">Flight Path Angle</td><td>0.1 degree (*)</td><td>0.1 degree</td></tr>
<tr><td colspan="2">Temperature</td><td>1 degree</td><td>1 degree</td></tr>
<tr><td colspan="2">(*) A Display resolution of 0.01 degree is recommended</td><td></td><td></td></tr>
</table></td></tr>
<tr><td>5</td><td>The navigation database must contain all the necessary data/information to fly the published APV BARO-VNAV approach. The navigation database must contain the waypoints and associated vertical information (e.g. VPA) for the procedure.
Vertical Constraints associated with published procedures must be automatically extracted from the navigation database upon selecting the approach procedure.</td></tr>
<tr><td>6</td><td>Indication of loss of navigation (e.g. system failure) in the pilot's primary field of view by means of a navigation warning flag or equivalent indicator on the vertical navigation display.</td></tr>
<tr><td>7</td><td>The aircraft must display barometric altitude from two independent altimetry sources, one in each pilots' primary field of view. When single pilot operation is permitted, the two displays must be visible from the pilot position.</td></tr>
</table>

7.3 Recommended Function for RNP APCH

<table>
<tr><th>Item</th><th>Functional Description</th></tr>
<tr><td>1</td><td>Capability, following ATC instructions, to immediately provide horizontal track deviation indications relative to the extended final approach segment, in order to facilitate the interception of this extended final approach segment from a radar vector.</td></tr>
<tr><td>2</td><td>Course selector of the deviation display automatically slaved to the RNAV computed path.

Note: Systems with electronic map display in the pilot's primary field of view having a depiction of the active route are sufficient.</td></tr>
</table>

7.4 Recommended Function for APV BARO-VNAV operation

Item	Functional Description
1	Temperature compensation: Capability to automatically adjust the vertical flight path for temperature effects. The equipment should provide the capability for entry of altimeter source temperature to compute temperature compensation for the vertical flight path angle. The system should provide clear and distinct indication to the flight crew of this compensation/adjustment.
2	Capability to automatically intercept the vertical path at FAP using a vertical fly by technique. Note: Vertical Fly By performance is described in ED-75 B paragraphs 1.5.7.2 and 3.2.8.5

8. AIRWORTHINESS COMPLIANCE

8.1 General

This section details a means of airworthiness compliance for new or modified installations (Para 8.2) and for existing installations (Para 8.3). It also details specific points that should be considered during these approval processes (Para 8.4).

Relevant documentation demonstrating airworthiness compliance should be available to establish that the aircraft is equipped with an RNAV systems meeting RNP APCH requirements without or with vertical guidance (APV BARO-VNAV).

8.2 New or Modified Installations

In demonstrating compliance with this AMC, the following specific points should be noted:

The applicant will need to submit to the Agency a compliance statement which shows how the criteria of this AMC have been satisfied. The statement should be based on a plan, agreed by the Agency at an early stage of the implementation programme. The plan should identify the certification data to be submitted which should include, as appropriate, a system description together with evidence resulting from the activities defined in the following paragraphs.

Compliance with the airworthiness requirements for intended function and safety may be demonstrated by equipment qualification, system safety analysis, confirmation of appropriate software design assurance level (i.e. consistent with paragraph 6.4), performance analyses, and a combination of ground and flight tests. To support the approval application, design data will need to be submitted showing that the objectives and criteria of Sections 6 and 7 of this AMC have been satisfied.

Use of the RNAV systems and the manner of presentation of lateral and vertical (if provided) guidance information on the flight deck should be evaluated to show that the risk of flight crew error has been minimised.

8.2.1 Specific Installation criteria

The following points need to be taken into consideration during the airworthiness approval process.

a) Where other conventional navigation systems, apart from the RNAV system, provide display and/or guidance to a flight director/Autopilot, means should be provided for:
  - a navigation system source selector as the only means of selection;
  - clear annunciation of the selected navigation system on or near the navigation display;
  - display of guidance information appropriate to the selected navigation system; and

- delivery of guidance information to a flight director/autopilot appropriate to the selected navigation system.

b) Annunciation for flight director, autopilot and selected navigation system should be consistent, and compatible with the original design philosophy of the cockpit.

c) Loss of navigation capability should be indicated to the flight crew.

d) Equipment failure scenarios involving conventional navigation systems and the RNAV system(s) should be evaluated to demonstrate that:
   - adequate alternative means of navigation are available following failure of the RNAV system; and
   - reversionary switching arrangements, e.g. VOR/GPS#2 on HSI#1, do not lead to misleading or unsafe display configurations.

   The evaluation should consider also the probability of failures within the switching arrangements.

e) If barometric altitude input is used by the RNAV system (e.g. Baro aiding for RAIM function), loss of altitude information should be indicated by the RNAV system.

f) The coupling arrangements between the RNAV system and the flight director/automatic pilot should be evaluated to show compatibility and to demonstrate that operating modes, including RNAV system failures modes, are clearly and unambiguously indicated to the flight crew.

g) The use of the RNAV system and the manner of presentation of lateral and vertical (if provided) guidance information on the flight deck should be evaluated to show that the risk of flight crew error has been minimised. The crew should be aware, at any time, of the system used for navigation.

h) The installation configuration features provided by the RNAV system which affect airworthiness approval or operational criteria, such as: external CDI selection; external CDI calibration; entering of GPS antenna height above ground; serial Input/Output port configuration; reference datum, should not be selectable by the pilot. Instructions on how to configure the RNAV system for the particular installation should be listed in the appropriate manual.

i) Controls, displays, operating characteristics and pilot interface to RNAV system should be assessed in relation to flight crew workload, particularly in the approach environment. Essential design considerations include:
   - Minimising reliance on flight crew memory for any system operating procedure or task. Developing a clear and unambiguous display of system modes/sub-modes and navigational data with emphasis on enhanced situational awareness requirements for any automatic mode changes, if provided.
   - Use of context sensitive helps capability and error messages (for example, invalid inputs or invalid data entry messages should provide a simple means to determine how to enter ‘valid’ data).
   - Placing particular emphasis on the number of steps and minimising the time required to accomplish flight plan modifications to accommodate ATS clearances, holding procedures, runway and instrument approach changes, missed approaches and diversions to alternate destinations.
   - Minimising the number of nuisance alerts so the flight crew will recognise and react appropriately when required.

8.3 Existing Installations

Aircraft that are approved for RNP AR APCH operations are considered compliant with this AMC.

An existing statement in the AFM that indicates the aircraft is approved:

- to perform RNP 0.3 GNSS approaches or,

- for instrument approaches including a specification of RNP GNSS capability that meets RNP 0.3

is considered acceptable for lateral performance.

If this is not the case, the applicant will need to submit to the Agency a compliance statement which shows how the criteria of this AMC have been satisfied for existing installations. Compliance may be established by inspection of the installed system to confirm the availability of required features and functionality. The performance and integrity criteria of Sections 6 and 7 may be confirmed by reference to statements in the Aircraft Flight Manual or to other applicable approvals and supporting certification data. In the absence of such evidence, supplementary analyses and/or tests may be required.

To avoid unnecessary regulatory activity, the determination of eligibility for existing systems should consider acceptance of manufacturer documentation. In this specific case, an AFM amendment is recommended to reflect the RNP APCH aircraft capability. The addition of this aircraft capability in the AFM without any technical modification applied to the aircraft could be considered as a Minor change by the Agency.

8.4 Specific Installation assessment

8.4.1 Lateral and vertical Fly-By transition mechanism

The applicant should demonstrate that the turn indication during lateral fly-by transitions is accurate enough to keep the aircraft within the theoretical transition area as described in ED-75 B paragraph 3.2.5.4. Lateral Fly-by transition assessment should be evaluated in manual and in autopilot mode. If the equipment provides positive course guidance through the turn (during the fly-by transition), then no specific flight test is required.

The applicant should demonstrate that the vertical indication during vertical fly-by transitions is accurate enough to keep the aircraft within the profile described in ED-75 B paragraph 3.2.8.5. Vertical Fly-by transition assessment should be evaluated in manual and in autopilot mode. It is recalled that momentary deviation below the published minimum procedure altitude at the FAP is acceptable provided the deviation is limited to no more than 50 feet assuming no VNAV equipment error.

8.4.2 Enhanced navigation displays

It is recognised that enhanced navigation display (such as IFR approved electronic moving map or enhanced EHSI) improves crew lateral situational awareness and navigation monitoring. It is strongly recommended that the RNAV installation incorporates an IFR approved moving map display. This may be a stand-alone display or may be integrated within the aircraft electronic display system or directly integrated within the GNSS stand-alone receiver. For certain cases an enhanced navigation display is required (see Para 7.1 Item 1).

The graphical map display should incorporate at least the active flight plan, map ranges consistent with the flight operation, available navigation aids, and airports. Design and installation of enhanced navigation display should be approved during the approval process; in particular the evaluation of the man-machine interface (colour, symbol, cluttering aspect, display location, display size, etc.).

Enhanced navigational display is considered an essential function for the crew to verify the approach procedure loaded from the navigational database. This display is also a key element for the navigation crew monitoring (e.g. flight plan progress).

8.4.3 Intermixing of equipment

Simultaneous use of RNAV systems with different crew interfaces can be very confusing and can lead to problems when they have conflicting methods of operation and conflicting display formats. For approach operations, simultaneous use of RNAV equipment which is not identical or compatible is not permitted.

9. AIRCRAFT FLIGHT MANUAL/PILOT OPERATING HANDBOOK

For new or modified aircraft, the Aircraft Flight Manual (AFM) or the Pilot's Operating Handbook (POH), whichever is applicable, should provide at least the following information:

a) A statement which identifies the equipment and aircraft build or modification standard certificated for RNP APCH operation with or without vertical guidance (APV BARO-VNAV). This may include a very brief description of the RNAV/GNSS system, including the RNAV/GNSS airborne equipment software version, CDI/HSI equipment and installation and a statement that it is suitable for RNAV operations. A brief introduction to the RNAV(GNSS) approach concept using ICAO RNP APCH terminology may also be included.

b) Appropriate amendments or supplements to cover RNP APCH approach operations in the following sections:

- Limitations – including use of VNAV, FD and AP; currency of navigation database; crew verification of navigation data; availability of RAIM or equivalent function; restrictions on use of GNSS for conventional Non Precision Approaches.
- Normal Procedures
- Abnormal Procedures – including actions in response to a Loss of Integrity (e.g. 'RAIM Position Warning', (or equivalent) message or a 'RAIM not available', (or equivalent) message).

Note: This limited set assumes that a detailed description of the installed system and related operating instructions and procedures are available in other approved operational or training manuals.

10. RNP APCH OPERATIONAL CRITERIA

This section describes acceptable operational criteria for approach operations, subject to the limitations given below. The operational criteria assume that the corresponding installation/airworthiness approval has been granted by the Agency.

Operational criteria apply to the use of the RNAV system for RNP APCH operations on any aircraft operated under IFR in accordance with EU legislation or the applicable operational regulations in the fields for which the EU legislation has not yet been established.

Operations of the RNAV system should be in accordance with the AFM or AFM supplement. The operational procedures to be addressed by the operator are detailed in APPENDIX 4. The (Master) Minimum Equipment List (MMEL/MEL) should be amended to identify the minimum equipment necessary to satisfy operations using the RNAV system.

The operator should determine the operational characteristics of the procedure to be flown. It is recommended that the process described in paragraph 10.3 and APPENDIX 2 of this AMC should be followed to validate its operational use by the crew.

Depending on the aircraft capability and the approach procedure, RNP APCH procedures may be conducted with lateral (LNAV), lateral/vertical (LNAV/VNAV) or equivalent mode engaged, and coupling with either a flight director or autopilot.

Prior to the operation, the operator needs to be authorised by his/her competent authority for such operations.

10.1 Flight Operations Documentation

The relevant parts and sections of the Operations Manual (e.g., Aircraft Operations Manual, check lists, training of crew) should be revised to take account of the operating procedures detailed in this section and, in particular those in APPENDIX 4. The operator should make timely amendments to the Operations Manual to reflect relevant RNP APCH procedure without or with vertical guidance (APV BARO-VNAV) and database checking strategies. Manuals and check lists need to be submitted for review by the responsible authority as part of the authorisation process.

The aircraft operator should propose an amendment to the Minimum Equipment List (MEL) appropriate to RNP APCH operations.

10.2 Flight Crew Training

Each pilot should receive appropriate training, briefings and guidance material in order to safely conduct RNP APCH operations without or with vertical guidance (APV BARO-VNAV). This material and training should cover both normal and abnormal procedures. Standard training and checking, such as recurrent aeroplane/STD training and proficiency checks, should include RNP APCH procedures. Based on this, the operator should determine what constitutes a qualified crew.

The operator should ensure that during line operations each pilot can perform assigned duties reliably and expeditiously for each procedure to be flown in:

a) normal operations and

b) abnormal operations

The operator should ensure that altimeter settings procedures and cold temperature limitations during APV BARO-VNAV operation are respected.

a) Altimeter setting

Flight Crews should take precautions to switch altimeter settings at appropriate times or locations and request a current altimeter setting if the reported setting is not recent, particularly at times when pressure is reported or is expected to be rapidly decreasing. Remote (regional) altimeter settings are not allowed.

Note: The operational crosscheck between altimeter read-out and charted altitude values at FAF or other profile fixes does not protect against altimeter setting errors.

b) Cold Temperature

When cold weather temperatures exist, the pilot should check the chart for the instrument approach procedure to determine the limiting temperature for the use of BARO-VNAV capability. If the airborne system contains a temperature compensation capability, manufacturer instructions should be followed for use of the BARO-VNAV function, and the operational use of the temperature compensation function must be authorised by the Air Navigation Service Provider.

A training programme should be structured to provide sufficient theoretical and practical training. An example of training syllabus is described in APPENDIX 5.

10.3 Aerodrome competence and Operator verification

Before planning a flight to an aerodrome (destination or alternate) with the intent to use an RNAV procedure contained in the Navigation Database, the operator should determine the operational characteristics of the procedure in accordance with EU OPS 1.975 or the applicable operational regulations. Further details are provided in APPENDIX 2.

Based on this assessment, the appropriate information should be given to the crew. If the aerodrome access requires a specific competence, the designated crew shall have a validated competence.

Note: This AMC addresses only RNP APCH procedures which are designed with straight segment (e.g. T or Y approach). It is therefore anticipated that in most cases no specific competence should be required to fly such approach procedure.

10.4 Navigation Database Management

10.4.1 Operator involved in the operation of aeroplanes for commercial air transportation

EU-OPS 1.873 for the management of navigation database applies.

10.4.2 Operator not involved in the operation of aeroplanes for commercial air transportation

The operators should not use a navigation database for RNP APCH operations unless the navigation database supplier holds a Type 2 Letter of Acceptance (LoA) or equivalent.

An EASA Type 2 LoA is issued by EASA in accordance with EASA OPINION Nr. 01/2005 on 'The Acceptance of Navigation Database Suppliers' dated 14 Jan 05. The FAA issues a Type 2 LoA in accordance with AC 20-153, while Transport Canada (TCCA) issues an Acknowledgement Letter of an Aeronautical Data Process using the same basis. Both the FAA LoA and the TCCA Acknowledgement Letter are seen to be equivalent to the EASA LoA.

EUROCAE/RTCA document ED-76/DO-200A Standards for Processing Aeronautical Data contains guidance relating to the processes that the supplier may follow. The LoA demonstrates compliance with this standard.

10.4.2.1 Non-approved Suppliers

If the operator's supplier does not hold a Type 2 LoA or equivalent, the operator should not use the electronic navigation data products unless the Authority has approved the operator's procedures for ensuring that the process applied and the delivered products have met equivalent standards of integrity. An acceptable methodology is described in APPENDIX 3 of this AMC.

10.4.2.3 Quality Monitoring

The operator should continue to monitor both the process and the products in accordance with the quality system required by the applicable operational regulations.

10.4.2.4 Data Distribution

The operator should implement procedures that ensure timely distribution and insertion of current and unaltered electronic navigation data to all aircraft that require it.

10.5 Reportable Events

A reportable event is one that adversely affects the safety of the operation and may be caused by actions/events external to the operation of the aircraft navigation system. The operator should have in place a system for investigating such an event to determine if it is due to an improperly coded procedure, or a navigation data base error. Responsibility for initiating corrective action rests with the operator.

For those operators for whom approval is granted under EU OPS 1, the following events should be the subject of Occurrence Reports (see EU-OPS 1.420):

Technical defects and the exceeding of technical limitations, including:

a) Significant navigation errors attributed to incorrect data or a data base coding error.
b) Unexpected deviations in lateral/vertical flight path not caused by pilot input or erroneous operation of equipment.
c) Significant misleading information without a failure warning.
d) Total loss or multiple navigation equipment failure.
e) Loss of integrity (e.g. RAIM) function whereas integrity was predicted to be available during the pre-flight planning.

11. AVAILABILITY OF DOCUMENTS

JAA documents are available from the JAA publisher Information Handling Services (IHS). Information on prices, where and how to order is available on the JAA website and at www.jaa.nl .

EASA documents may be obtained from EASA (European Aviation Safety Agency), 101253, D-50452 Koln, Germany. Website: www.easa.europa.eu

EUROCAE documents may be purchased from EUROCAE, 102 rue Etienne Dolet, 92240 MALAKOFF, France (Fax: 33 1 46 55 62 65). Website: http://boutique.eurocae.net/catalog/.

FAA documents may be obtained from Superintendent of Documents, Government Printing Office, Washington, DC 20402-9325, USA. Website: http://www.gpoaccess.gov/.

RTCA documents may be obtained from RTCA Inc, 1828 L Street, NW., Suite 805, Washington, DC 20036, USA (Tel: 1 202 833 9339; Fax 1 202 833 9434). Website: www.rtca.org.

ICAO documents may be purchased from Document Sales Unit, International Civil Aviation Organisation, 999 University Street, Montreal, Quebec, Canada H3C 5H7, (Fax: 1 514 954 6769, e-mail: sales_unit@icao.org) or through national agencies.

APPENDIX 1: GLOSSARY

The following are definitions of key terms used throughout this AMC.

Aircraft-Based Augmentation System (ABAS): An augmentation system that augments and/or integrates the information obtained from the other GNSS elements with information available on board the aircraft.

APV (Approach Procedure with Vertical guidance): An instrument approach procedure which utilises lateral and vertical guidance but does not meet the requirements established for precision approach and landing operations.

Area navigation (RNAV): A method of navigation which permits aircraft operation on any desired flight path within the coverage of station-referenced navigation aids or within the limits of the capability of self-contained aids, or a combination of these.

Accuracy: The degree of conformance between the estimated, measured, or desired position and/or the velocity of a platform at a given time, and its true position or velocity. Navigation performance accuracy is usually presented as a statistical measure of system error and is specified as predictable, repeatable and relative.

ASE (Altimetry System error)**:** Altimetry error refers to the electrical output and includes all errors attributable to the aircraft altimetry installation including position effects resulting from normal aircraft flight attitudes.

Availability: An indication of the ability of the system to provide usable service within the specified coverage area and is defined as the portion of time during which the system is to be used for navigation during which reliable navigation information is presented to the crew, automatic pilot, or other system managing the flight of the aircraft.

BARO-VNAV (Barometric Vertical NAVigation) is a navigation system that presents to the pilot a computed vertical guidance based on barometric altitude.

Basic GNSS operation: Operation that are based on GNSS Aircraft Based Augmentation System (ABAS). An ABAS system is typically a GNSS receiver with fault detection compliant to E/TSO C 129a, E/TSO-C145() or E/TSO-C146().

Continuity of Function: The capability of the total system (comprising all elements necessary to maintain aircraft position within the defined airspace) to perform its function without non-scheduled interruptions during the intended operation.

DA(H): Decision altitude (DA) or Decision height (DH). A specified altitude or height in the precision approach or approach with vertical guidance at which a missed approach must be initiated if the required visual reference to continue the approach has not been established.

FAP: Final Approach Point.

Fault Detection and Exclusion (FDE): FDE is a receiver processing scheme that autonomously provides integrity monitoring for the position solution, using redundant range measurements. The FDE consist of two distinct parts: fault detection and fault exclusion. The fault detection part detects the presence of an unacceptably large position error for a given mode of flight. Upon the detection, fault exclusion follows and excludes the source of the unacceptably large position error, thereby allowing navigation to return to normal performance without an interruption in service.

GNSS stand-alone receiver: A GNSS system incorporating the GNSS sensor, the navigation capability and the navigation data base.

GNSS sensor: A GNSS system incorporating only the GNSS receiving and positioning part. It doesn’t incorporate the navigation capability and the navigation data base.

HCE (Horizontal Coupling Error): The vertical error component of an along track positioning error

Integrity: The ability of a system to provide timely warnings to users when the system should not be used for navigation.

MDA(H): Minimum descent altitude (MDA) or minimum descent height (MDH). A specified altitude or height in a non-precision approach or circling approach, below which, descent should not be made without the required visual reference.

NSE (Navigation System Error): The difference between true position and estimated position

OCA/H: In a precision approach procedure (or APV), the OCA/H is defined as the lowest altitude/height at which a missed approach must be initiated to ensure compliance with the appropriate obstacle clearance design criteria.

On board Monitoring and Alerting function: This function is the main element which determines if the navigation system complies with the necessary safety level associated to a RNP application; it relates to both lateral and longitudinal navigation performance. On-board performance monitoring and alerting allows the flight crew to detect that the RNAV system is not achieving the navigation performance required. On-board performance monitoring and alerting is concerned with the monitoring of all type of errors which may affect the aircraft ability to follow the desired flight path.

TCH: Threshold Crossing Height. The height of the Glide Path above the threshold.

TSE (Total System Error): The difference between true position and desired position. This error is equal to the root sum square (RSS) of the Flight Technical Error (FTE), Path Definition Error (PDE), and Navigation System Error (NSE).

PDE (Path Definition Error): The difference between the defined path and the desired path.

Receiver Autonomous Integrity Monitoring (RAIM): A technique whereby a GNSS receiver/processor determines the integrity of the GNSS navigation signals using only GPS signals or GPS signals augmented with altitude. This determination is achieved by a consistency check among redundant pseudorange measurements. At least one satellite in addition to those required for navigation should be in view for the receiver to perform the RAIM function.

RNAV System: A navigation system which permits aircraft operation on any desired flight path within the coverage of station-referenced navigation aids or within the limits of the capability of self-contained aids, or a combination of these. A RNAV system may be included as part of a Flight Management System (FMS).

RNAV(GNSS) approach: A GNSS RNAV approach promulgated by a State and designed in accordance with PANS-OPS Criteria Doc 8168, Volume II, Part III, Section 1, Chapter 2 and Section 3, Chapter 3 (Basic GNSS). Such approach should be flown by using an airborne RNAV system approved for RNP APCH operations.

SBAS: Satellite Based Augmentation System. SBAS augments core satellite constellation by providing ranging, integrity and correction information via geostationary satellites. This system comprises a network of ground reference stations that observe satellites signals, and master stations that process observed data and generate SBAS messages for uplink to the geostationary satellites, which broadcast the SBAS message to the users.

RNP APCH: RNP AProaCH. A RNP approach defined in the ICAO Performance Based Manual (PBN) manual. An approach equivalent to the RNAV (GNSS) one.

TSO-C129()/ ETSO- C129a GPS Class A equipment: Equipment incorporating both the GNSS sensor and navigation capability. This equipment incorporates RAIM as defined by TSO/ETSO-C129( ).

TSO-C129()/ ETSO-C129 a GPS Class B and C equipment: GNSS sensor providing GNSS data (position, integrity,..) to an integrated navigation system (e.g. FMS).

TSO-C146() Class GAMMA: This functional class corresponds to equipment consisting of both the GNSS/SBAS position sensor and a navigation function, so that the equipment provides path deviations relative to a selected path. The equipment provides the navigation function required of a stand-alone navigation system. This equipment also provides integrity in the absence of SBAS signal through the use of FDE. In addition, this class of equipment requires a data base, display outputs and pilot controls.

TSO-C145() class BETA: Equipment consisting of a GNSS/SBAS sensor that determines position (with integrity) and provides position and integrity to an integrated navigation system (e.g. flight management system, multi-sensor navigation system). This equipment also provides integrity in the absence of the SBAS signal through the use of fault detection and exclusion (FDE).

TSO-C146( ) or TSO-C145( ) Operational Class 1: This operational class supports oceanic and domestic en-route, terminal and non precision approach, and departure operation.

TSO- C146( ) or TSO-C145( ) Operational Class 2: This operational class supports oceanic and domestic en-route, terminal and non precision approach, LNAV/VNAV and departure operation.

TSO-C146( ) or TSO-C145 ( ) Operational Class 3: This operational class supports oceanic and domestic en-route, terminal and non precision approach, LNAV/VNAV, LPV and departure operation.

'T' approach: T approach is defined in ICAO document 8168 and in RTCA/EUROCAE DO 201A/ED 77. 'T' approach is composed of two initial approach segments perpendicular to the intermediate approach segment.

Vertical Navigation: A method of navigation which permits aircraft operation on a vertical flight profile using altimetry sources, external flight path references, or a combination of these.

VPA (Vertical Path Angle): Angle of the published final approach descent.

VTF: Vector To Final.

VSR: Reference Stall Speed.

'Y' approach: Y approach is defined in ICAO document 8168 and in RTCA/EUROCAE DO 201A/ED 77. 'Y' approach is derived from the 'T' approach but the initial segments are establishing at 70° to the intermediate segment rather than 90°.

APPENDIX 2: OPERATIONAL CHARACTERISTICS OF THE PROCEDURE AND ITS OPERATIONAL USE

The operator should show evidence that consideration has been given to the evaluation of any new or modified RNP APCH procedures.

RNP APCH procedure should be designed using straight segments; the operator should check that the selected procedure fulfils this requirement.

Particular attention should be paid to procedures:

- in mountainous environments,
- within the proximity of well-known obstacles,
- that may require adequate knowledge for the aerodrome access or aerodrome competence qualification, as specified in EU-OPS 1.975 or the applicable operational requirements.

Competence may be required specifically for this RNAV procedure or the procedure may be published for an aerodrome already listed as requiring an aerodrome competence. This may be aircraft type related and subject to periodic revalidation.

- In the absence of radar coverage,
- When missed approach trajectory involve turns, especially at low altitudes,
- Subject to a declared exemption to the procedure design rules specified by the ICAO PANS OPS,
- Every other case considered necessary to be evaluated by the operator.

The operator may develop an internal process (e.g. filtering methods or tools covering the AIP review) to detect RNP APCH procedure(s) showing one or more of the above-listed characteristics.

The operational evaluation of a RNP APCH procedure showing evidence of the above-mentioned operational characteristics may include, at operator discretion, an approach conducted with the aircraft in VMC or the use of a full flight simulator (FFS) in order to evaluate if the procedure is correctly executed by the RNAV system and fly-able with the aircraft type.

APPENDIX 3: ALTERNATE NAVIGATION DATABASE INTEGRITY CHECK

If operator's navigation data base supplier has no Type 2 LOA, the operator should develop and describe a method to demonstrate an acceptable level of integrity of the navigation data base content used by the RNAV system on board the aircraft.

The operator should implement navigation data base integrity checks for all RNP APCH procedures they wish to operate, using manual verification procedures or appropriate software tools, at each AIRAC Cycle.

The objective of this integrity check is to identify any significant discrepancies between the published charts/procedures and the navigation database content.

Integrity checks may be conducted by a designated third party, under the operator responsibility.

1 Elements to be verified

At least the following elements of an RNP APCH should be verified:

- Coordinates/location verification of IAF, IF, FAF, MAPt, and other waypoints between IAF and MAPt (if any)
- Tracks between these waypoints
- Distance between these waypoints
- Vertical path angle (for APV BARO-VNAV operation)

2 Means to verify those elements

2.1 The Operator verification process

The operator should, at the very least, verify the information listed in paragraph 1 of this Appendix, by comparison with the official published data.

As the data may evolve at each AIRAC Cycle, this verification should be done at every AIRAC cycle using comparison with source documents or a reference data base (gold standard).

The operator should describe the method used to verify the navigation data base integrity which can be based on a:

a) manual method, with or without software support, whereby the airborne data base is compared with the original published data, or

b) recurrent method with a reference database, whereby any changes identified between the latest data base and the reference data base are checked against the original published data. Once the latest data base has been verified, it becomes the reference data base for the next AIRAC cycle.

The recurrent method relies on the integrity of the initial data base, and requires that the check of every RNP APCH procedure has been properly conducted and validated at the very first time. It also relies on the assumption that every change in the data base is properly identified and checked. It is recommended that software tools are used to compare the contents of one (N) AIRAC cycle data base with the contents of the previous (N-1) AIRAC cycle data base.

Whatever the method, data to be checked must come from the final source to be loaded on the aircraft.

2.2 The means to enable this verification

In many cases, the RNAV system and an enhanced navigation display are necessary to access the data (on the aircraft or on a flight simulator).

An RNAV system comparable to the one installed on the aircraft (i.e. using the same algorithms) may also be used, as well as appropriate simulation software tools. The RNAV system manufacturer should be consulted on the adequacy of specific software for this purpose.

Data may also be acquired through a tool able of unpacking the data encoded on the files (e.g. decompactor) developed by the RNAV system manufacturer.

Whatever software tool is used, it should be validated for its intended use by the operator.

3 Feed back and reporting errors found

In case of errors found, the operator should take appropriate actions.

In particular, significant errors (i.e. those that would affect the flight path of the aircraft) should be reported to the database supplier and the competent authority and affected procedures should be prohibited by a company instruction or NOTAM.

Note: Integrity checks could be conducted for several operators by a same designated third party. In this case, it is strongly recommended that any problem recorded by this third party be reported to all its client operators.

APPENDIX 4: OPERATIONAL PROCEDURES

This Appendix should be used by the operator to amend the relevant parts and sections of the Operations Manual as described in 10.1 to support these types of operations.

1 Normal Procedures

1.1 Pre-flight Planning

Operators and flight crew intending to conduct operations on RNP APCH procedures must file the appropriate flight plan suffixes. The on-board navigation data must be current and must include the appropriate procedures.

In addition to the normal pre-flight planning, the following additional checks must be carried out:

a) The instrument approach chart should clearly identify the RNP APCH operation as RNAV$_{(GNSS)}$ or equivalent (e.g.: RNAV$_{(GNSS)}$ RWY 27,…). The operator should determine in accordance with the promulgated OCA(H) and the operational requirement (e.g. EU-OPS 1.430) the Minimum Descent Altitude/Height (MDA(H)) for LNAV approaches or the Decision Altitude/Height (DA(H)) for APV BARO-VNAV operation.

b) Flight crew must ensure that RNP APCH procedures which may be used for the intended flight (including alternates aerodromes) are selectable from a valid navigation data base (current AIRAC cycle) and are not prohibited by a company instruction or NOTAM.

   Flight crew could check approach procedures (including alternate aerodromes) as extracted by the system (e.g. CDU flight plan page) or presented graphically on the moving map, in order to confirm the correct loading and the reasonableness of the procedure content. The vertical path of the APV BARO-VNAV procedure could be checked as extracted from the navigation data base on the RNAV Man Machine Interface (e.g. ~~M~~CDU).

   If above verification is not satisfactory, the flight crew should not use the procedure, and not consider this approach(es) during the selection of aerodromes for the intended flight.

c) Flight crew should ensure sufficient means are available to navigate and land at the destination or at an alternate aerodrome in the case of loss of RNP APCH airborne capability.

   In particular, the pilot should check that:

   - a non-RNP APCH procedure is available at the alternate, where a destination alternate is required
   - at least one non-RNP APCH procedure is available at the destination aerodrome, where a destination alternate is not required

d) Operators and flight crews must take account of any NOTAMs or operator briefing material that could adversely affect the aircraft system operation, or the availability or suitability of the procedures at the airport of landing, or any alternate airport.

e) If the missed approach procedures are based on conventional means (VOR, NDB), the appropriate airborne equipment required to fly this procedure must be installed in the aircraft and must be operational. The associated ground-based navaids must also be operational.

   If the missed approach procedure is based on RNAV (no conventional or dead reckoning missed approach available), the appropriate airborne equipment required to fly this procedure must be available and serviceable on board the aircraft.

f) For those GNSS systems relying on RAIM, its availability 15 min before Estimated Time of Arrival (ETA) until 15 min after ETA should be verified during the pre-flight planning. In the event of a predicted continuous loss of fault detection of more than five (5) minutes, the flight planning should be revised (e.g. delaying the departure or planning a different approach procedure).

Note 1: For certain systems, prediction is not systematic but is only required in specific cases and shall be detailed in the relevant section of the AFM

Note 2: RAIM availability prediction services may be provided to users by the air navigation service provider (ANSP), an avionics manufacturer or other entities.

g) Any MEL restriction should be observed

1.2 Prior to Commencing the Procedure

In addition to normal procedure prior to commencing the approach (before the IAF and in compatibility with crew workload), the flight crew must verify the correctness of the loaded procedure by comparison with the appropriate approach charts. This check must include:

a) The waypoint sequence.

b) Reasonableness of the tracks and distances of the approach legs, and the accuracy of the inbound course and mileage of the final approach segment.

Note: As a minimum, this check could be a simple inspection of a suitable map display.

c) The vertical path angle.

For multi-sensor systems, the crew must verify during the approach that GNSS sensor is used for position computation.

For an RNAV system with ABAS requiring barometric corrected altitude, the current airport barometric altimeter setting, should be input at the appropriate time, consistent with the performance of the flight operation.

For those GNSS systems relying on RAIM and necessitating a check of its availability for RNP APCH, the flight crew should perform a new RAIM availability check if ETA is more than 15 minutes different from the ETA used during the pre-flight planning. This check is also performed automatically for ETSO/TSO-C129a Class A1 receiver, 2 NM before the FAF.

Note: Systems providing RNP alerts that reflect loss of GNSS integrity are considered acceptable and no flight crew RAIM availability check is required.

For APV BARO-VNAV operation, the crew must confirm the correct altimeter setting. The procedure must only be flown with:

a) a current local altimeter setting source available; and

b) the QNH/QFE, as appropriate, set on the aircraft's altimeters.

Procedures using a remote (regional) altimeter setting source cannot support APV BARO-VNAV approach.

For APV BARO-VNAV operation, pilots are responsible for any necessary cold temperature compensations to all published minimum altitudes/heights. This includes:

a) the altitudes/heights for the initial and intermediate segment(s);

b) the DA/H; and

c) subsequent missed approach altitudes/heights.

APV BARO-VNAV procedures are not permitted when the aerodrome temperature is below the promulgated minimum aerodrome temperature for the procedure, unless the RNAV system is equipped with approved cold temperature compensation for the final approach.

ATC tactical interventions in the terminal area may include radar headings, 'direct to' clearances which by-pass the initial legs of an approach, interceptions of an initial or intermediate segments of an approach or the insertion of additional waypoints loaded from the data base. In complying with ATC instructions, the flight crew should be aware of the implications for the RNAV system.

a) The manual entry of coordinates into the RNAV system by the flight crew for operation within the terminal area is not permitted.

b) 'Direct to' clearances may be accepted to the Intermediate Fix (IF) provided that the resulting track change at the IF does not exceed 45°.

Note: Direct to clearance to FAF is not acceptable. Modifying the procedure to intercept the final approach course prior to the FAF is acceptable for radar vectored arrivals or at other times with ATC approval.

The lateral and vertical (for APV BARO-VNAV operation) definition of the flight path between the FAF and the Missed Approach Point (MAPt) must not be revised by the flight-crew under any circumstances.

1.3 During the Procedure

The final approach trajectory must be intercepted no later than the FAF in order for the aircraft to be correctly established on the final approach course before starting the descent (to ensure terrain and obstacle clearance).

The crew must check the RNAV approach mode annunciator (or equivalent) is properly indicating approach-mode integrity 2 NM before the FAF.

Note: This will not apply for certain RNAV system (e.g. aircraft already approved with demonstrated RNP capability). For such systems, other means are available including electronic map displays, flight guidance mode indications, etc., which clearly indicate to the crew that the approach mode is activated.

For APV BARO-VNAV operation, the crew should check that the two altimeters provide equivalent altitude (difference of 100 feet max) at or before FAF. This check must be made after the crew has set the correct altimeter setting.

The crew should also check the consistency between the VNAV guidance and the primary altimeters indications commensurate with pilot workload (e.g. after the aircraft is established on the vertical path).

During the descent, crew should check that the vertical speed is consistent with the VNAV angle to be flown.

The appropriate displays must be selected so that the following information can be monitored:

a) The RNAV computed desired path (DTK), and
b) Aircraft position relative to the lateral path (Cross-Track Deviation) for FTE monitoring
c) Aircraft position relative to the vertical path (for APV BARO-VNAV operation)

The crew should respect all published altitude and speed constraints.

The procedure must be discontinued:

a) If RNAV failure is annunciated (e.g. warning flag),
b) If the NSE alarm is triggered (e.g. RAIM alert),
c) In case of loss of the NSE alerting function (e.g. RAIM loss),
d) If lateral or vertical (if provided) FTE is excessive,
e) If VNAV trajectory is not consistent with aircraft altimetry system information or vertical speed information.

Note: Discontinuing the procedure may not be necessary for a multi-sensor RNAV system that includes demonstrated RNP capability without GNSS. Manufacturer documentation should be examined to determine the extent the system may be used in such configuration.

The missed approach must be flown in accordance with the published procedure. Use of the RNAV system during the missed approach is acceptable provided:

a) The RNAV system is operational (e.g. no loss of function, no RAIM alert, no failure indication, etc.).
b) The whole procedure (including the missed approach) is loaded from the navigation data base.

During the RNP APCH procedure, pilots must use a lateral deviation indicator, flight director and/or autopilot in lateral navigation mode.

Pilots of aircraft with a lateral deviation indicator (e.g. CDI) must ensure that lateral deviation indicator scaling (full-scale deflection) is suitable for the navigation accuracy associated with the various segments of the procedure (i.e., ±1.0 nm for the Initial and Intermediate segments, ±0.3 nm for the Final Approach segment, and ±1.0 nm for the Missed Approach segment).

All pilots are expected to maintain procedure centrelines, as depicted by on board lateral deviation indicators and/or flight guidance during all the approach procedure unless authorised to deviate by ATC or under emergency conditions.

For normal operations, cross-track error/deviation (the difference between the RNAV system computed path and the aircraft position relative to the path) should be limited to ± ½ the navigation accuracy associated with the procedure (i.e., 0.5 nm for the Initial and Intermediate segments, 0.15 nm for the Final Approach segment, and 0.5 nm for the Missed Approach segment).

Brief deviations from this standard (e.g. overshoots or undershoots) during and immediately after turns, up to a maximum of 1 times the navigation accuracy (i.e., 1.0 nm for the Initial and Intermediate segments), are allowable.

In addition, during APV BARO-VNAV procedures pilots must use a vertical deviation indicator, flight director and/or autopilot in vertical navigation mode.

Deviations above and below the vertical path must not exceed ±75 feet. Pilots must execute a Missed Approach if the vertical deviation exceeds the criteria above, unless the pilot has in sight the visual references required to continue the approach.

In the event of failure of one RNAV system during a procedure where two systems are necessary, the crew should abort the procedure if the failure occurs before FAF but could continue the approach if the failure occurs after FAF.

Use of GNSS altitude information by the crew is prohibited.

2 Abnormal Procedures

Abnormal procedures to address Cautions and Warnings resulting from the following conditions should be developed:

a) Failure of the RNAV system components, including those affecting Flight Technical Error (e.g. failures of the flight director or automatic pilot).

b) RAIM (or equivalent) alert or loss of integrity function.

In the event of communications failure, the flight crew should continue with the procedure in accordance with published lost communication procedures.

The flight crew should notify ATC of any problem with the RNAV system that results in the loss of the approach capability.

APPENDIX 5: FLIGHT CREW TRAINING SYLLABUS

The flight crew training programme should be structured to provide sufficient theoretical and practical training, using a simulator, training device, or line training in an aircraft, in the concept of RNP APCH operations without or with vertical guidance (APV BARO-VNAV) and the use of the aircraft's RNAV system in such operations to ensure that pilots are not just task-oriented. The following syllabus should be considered as minimum amendment to the training programme to support RNP APCH including APV BARO-VNAV operations:

Note: Operators who are already using procedures to fly other types of approaches, may receive appropriate credit for common training and procedural elements.

1 GENERAL RNAV CONCEPTS INCLUDING:

1. Theory of RNAV including differences between types of RNAV operations
2. Limitations of RNAV
3. Limitations of BARO-VNAV
4. Charting and database issues including:
   - i. Waypoint naming concepts
   - ii. Vertical path angle
   - iii. Fly-by and fly-over waypoints
5. Use of RNAV equipment including:
   - i. Verification and sensor management
   - ii. Tactically modifying the flight plan
   - iii. Addressing discontinuities
   - iv. Entering associated data such as:
     - Wind
     - Altitude/speed constraints
     - Vertical profile/vertical speed
6. Use of lateral navigation mode(s) and associated lateral control techniques
7. Use of vertical navigation mode(s) and associated vertical control techniques
8. R/T phraseology for RNAV operations
9. The implication for RNAV operations of systems malfunctions which are not RNAV related (e.g. hydraulic or engine failure)

2 RNP APCH concepts including:

1. Definition of RNP APCH operations and its direct relationship with RNAV (GNSS) procedures.
2. Regulatory requirements for RNP APCH operations
3. Required navigation equipment for RNP APCH operations:
   - i. GPS concepts and characteristics
   - ii. RNP/ANP requirements
   - iii. RAIM
   - iv. BARO-VNAV
   - v. MEL
4. Procedure characteristics
   - i. Chart depiction
   - ii. Aircraft display depiction
   - iii. Minima
5. Retrieving a RNP APCH(or a RNAV(GNSS)) approach procedure from the data base
6. Procedure change at destination airport, change arrival airport and alternate airport
7. Flying the procedure:
   - i. Use of autopilot, auto throttle and flight director
   - ii. Flight Guidance(FG) mode behaviour
   - iii. Lateral and vertical path management
   - iv. Adherence to speed and/or altitude constraints

v. Fly direct to a waypoint
vi. Determine lateral and vertical-track error/deviation
vii. Fly interception of an initial or intermediate segment of an approach following ATC notification
viii. Where the RNAV system supports interception of the extended final approach segment then flight crew should be trained in use of the function.
ix. The use of other aircraft equipment to support track monitoring, weather and obstacle avoidance
x. Contingency procedures in case of lateral mode failure (LNAV) and/or vertical mode failure (VNAV)

8. For APV BARO-VNAV operation, a clear understanding of specific crew requirements:
   i. for comparisons of VNAV guidance with primary altimeter information
   ii. for altitude crosschecks between primary altimeters (e.g. altimetry comparisons of 100 feet),
   iii. for temperature limitations on instrument procedures
   iv. for altimeter settings in term of currency, accuracy and integrity.
9. The effect of temperature deviation and its compensation
10. ATC procedures
11. Abnormal procedures
12. Contingency procedures